Puzzle Creek Mitigation Project

Year 1 Monitoring Report

Rutherford County, North Carolina

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Progress Document

For Review Purpose Only

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EXECUTIVE SUMMARY

The Puzzle Creek site was restored through a full delivery contract with the North Carolina Ecosystem Enhancement Program (NCEEP). This report documents Year 1 monitoring data for the five-year monitoring period. The goals for the restoration project are as follows:

- Improve hydrologic connectivity between creeks and floodplains;
- Reduce sediment and nutrient loading through restoration of riparian areas and stream banks;
- Create geomorphically stable conditions on the Puzzle Creek project site; and
- Improve aquatic and terrestrial habitat along the project corridor.

To accomplish these goals, the following objectives were implemented:

- Removal of anthropogenic impacts from the stream corridor and rehabilitation of incised and eroding streams by stabilizing stream channels and improving floodplain access;
- Improving impacted buffers to aid in nutrient removal from runoff and stabilizing stream banks to reduce bank erosion and sediment contribution to streams;
- Providing more stable and diverse channel features such as depositional riffles and bars, creating deeper pools and areas of water re-aeration, and providing woody debris to increase instream habitat quality and diversity;
- Establishment of riparian areas characterized by native vegetation, organic debris, and bi-annual flooding which are protected by a permanent conservation easement. The establishment of native streambank and floodplain vegetation are improving bank stability, and will eventually provide shading to decrease water temperature and cover, improving terrestrial wildlife habitat.

Eight vegetation monitoring plots 100 square meters (m^2) (10m x 10m) in size were used to estimate survival of the woody vegetation planted on-site. The Year 1 vegetation monitoring indicated an average survival of 632 stems per acre. The data shows that the Site is on track to meet both the interim stem survival criteria for Year 3 (320 stems per acre) and the final success criteria of 260 trees per acre by the end of Year 5.

The design implemented at the Puzzle Creek mitigation project site involved Priority Level I and II Restoration, and Enhancement Level I approaches. The resulting design will ultimately yield stable C-type channels for Puzzle Creek, and the project tributaries. Restoration and enhancement work were completed in accordance with the approved design approach provided in the mitigation plan for Puzzle Creek and its tributaries. Longitudinal profile and cross-section data indicate that the project streams have remained stable since baseline monitoring data were collected in February 2011. Additionally, as the photo logs included in this report show, the herbaceous cover at the project site is flourishing, and in conjunction with other erosion control measures like matting, is promoting bank stability on-site, while planted woody vegetation becomes more established. Based on geomorphic data presented in Appendix B, this Site is currently on track to meet the hydrologic and stream success criteria specified in the Puzzle Creek Mitigation Plan.

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 EEP's website. All raw data supporting the tables and figures in the appendices is available from EEP upon request.

1.0 PROJECT BACKGROUND AND ATTRIBUTES

The Puzzle Creek Restoration site is located approximately three miles northeast of Bostic, in Rutherford County, North Carolina (Figure 1). The project site is situated in the Broad River Basin, within North Carolina Division of Water Quality (NCDWQ) sub-basin 03-08-02 and United States Geologic Survey (USGS) hydrologic unit 03050105070050. The Puzzle Creek project area drains agricultural and forested land, as well as a small area occupied by residential development. The general area in which the project is located is rural in character, and is not likely to change significantly in the foreseeable future. The largest percentage of land use in the watershed currently is in forested cover for wildlife habitat and hunting as well as timber production. The percentage of land in the watershed available to agriculture is 27% with over 60% of the watershed remaining as forest land.

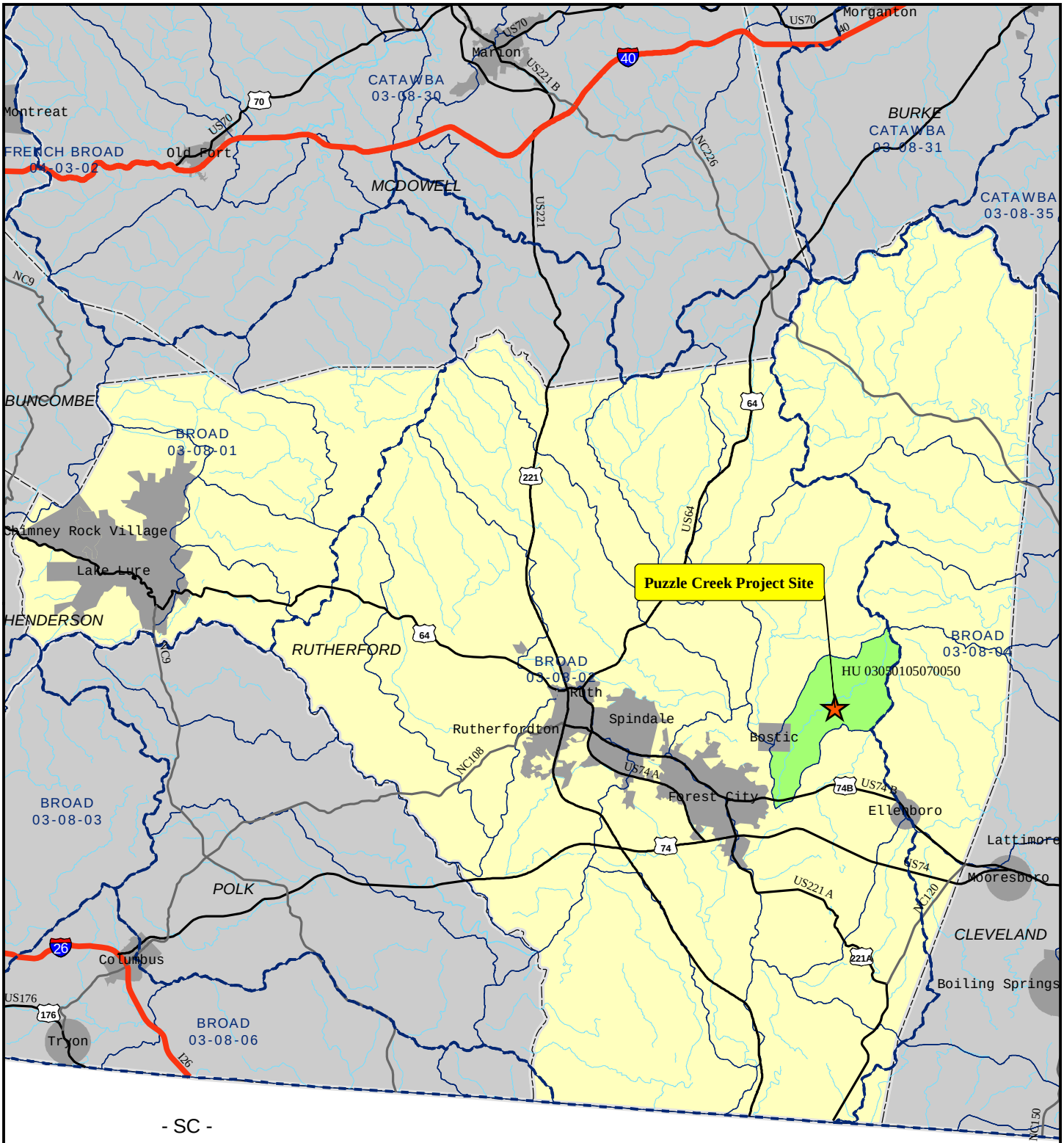
Orthophotography maps from the 1930's show residential and agricultural land use altering the Puzzle Creek watershed. Many streams were channelized to help mark property boundaries and to drain low lands for farming. Anthropogenic land use alteration and channelization of streams introduced instabilities from which the streams are still recovering. Incision, bank erosion, meander cutoffs, lateral bar formation, debris jams, and other ongoing stream processes typical of adjusting streams are found in the project reach. Segments of the unnamed tributary have achieved a degree of relative stability due to the presence of heavily wooded banks, developing floodplains which have been active in recent years, and bedrock that has prevented incision from becoming the driving factor in channel geomorphic development.

The project involved restoration or enhancement of two on-site streams: Puzzle Creek and a smaller unnamed tributary (UT) identified in the project as UT1. As noted in the Baseline Monitoring Report for Puzzle Creek, two additional unnamed tributaries (UT2 and UT3) were also restored. Total stream length across the project increased from approximately 4,849 LF to 5,073LF. The restoration and enhancement of 5,073 LF of stream within this project site has generated 4,966 stream mitigation units (SMUs).

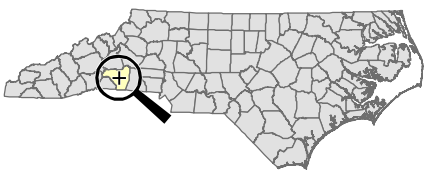
1.1 Location and Setting

The Puzzle Creek restoration site is located approximately three miles northeast of Bostic in Rutherford County, NC. To access the site from Interstate 26, take the Hwy 74 East exit, Exit 67, toward NC-108/Columbus/Rutherford. Continue on Hwy 74 East for approximately 23 miles and turn left at the Old Caroleen Road Exit. Continue on Old Caroleen Road and take a right onto Riverside Drive before making another right onto the Hwy 74 Bridge. After crossing the bridge, turn left onto Bostic Sunshine Road which temporarily merges with S Main Street. Continue on Bostic Sunshine Road/S Main Street until reaching Piney Mountain Church Road whereupon a right turn should be made to access the project site, located at 2321 Piney Mountain Church Road.

Unnamed tributary 1(UT 1) flows west then northwest from the upstream end of the Schafer property boundary to a break in the easement. UT1 continues northwest from the break in the easement to its confluence with Puzzle Creek. Reach 1 of Puzzle Creek begins at Piney Mountain Church Rd (SR 1007) and continues southwest to the confluence with UT1. Reach 2 of Puzzle Creek begins at the confluence of with UT1 and continues northwest to the property boundary. The project site is accessible from Piney Mountain Church Rd. and Washburn Rd. (Figure 1).



Map Inset



Rutherford County, NC

LEGEND:

- NCDWQ Sub-basin
- Counties
- USGS Hydrologic Unit
- Project Hydrologic Unit
- Rutherford County

0 1 2 4 Miles

Figure 1 Project Vicinity Map

Puzzle Creek Restoration Project
Rutherford County, NC

Ecosystem Enhancement Program

Baker

1.2 Mitigation Structure and Objectives

Table 1 summarizes project data for each reach and restoration approaches used. The design implemented at the Puzzle Creek mitigation project site involved both Priority Level 1 and 2 approaches. The resulting design should ultimately yield primarily a C-type channel for Puzzle Creek and its tributaries within the project reach. Restoration and enhancement work on Puzzle Creek and UT1were completed in accordance with the approved design approach provided in the mitigation plan for Puzzle Creek.

Table 1. Project Mitigation Structure and Objectives
Puzzle Creek Mitigation Project-NCEEP Project#92522

Project Segment or Reach ID	Existing Feet/ Acres	Mitigation Type	Approach	Target Stream Type	Footage or Acreage	Mitigation Ratio	Mitigation Units	Stationing	Comment
Puzzle Creek									
Reach 1	1,024LF	R	P1	C4/5	1,000 LF	1:1	1,000	0+00-10+00	Reroute channel through middle of valley, improve pattern, dimension and profile
Reach 2	600 LF	R	PII		634 LF	1:1	634	10+00-16+34	Pattern adjustment to address overly sinuous section, profile and dimension adjustments
UT1 (Reach 1)									
Subreach [A]	2,036 LF	R	PII		2,150 LF	1:1	2,150	00+00-21+50	Constraints prevented restoration; built bankfull benches
Subreach [A]	320 LF	E	LI	C4/5	320LF	1.5:1	213	21+50-24+70	Profile and dimension adjustments; improve floodplain access (narrow valley through this reach precluded pattern adjustments)
Subreach [A]	469 LF	R	PII		469 LF	1:1	469	24+70-29+39	Pattern and profile adjustments; improve floodplain benching
Subreach [A]	400LF	R	PII	C4/5	400 LF	1:1	400	32+12-36+12	Slight pattern and profile adjustments, lowering of bankfull elevation on right bank near confluence.
UT 2									
Reach 1	----	R	PII	-	52 LF	1:1	52	1+39-1+91	Bank grading and stabilization; invasives removal and re-planting with native riparian vegetation
UT 3									
Reach 1	----	R	PI	-	48 LF	1:1	48	0+63-1+11	Bank grading and stabilization; invasives removal and re-planting with native riparian vegetation

Mitigation Unit Summations

Stream (LF)	Riparian Wetland (Ac)	Nonriparian Wetland (Ac)	Total Wetland (Ac)	Buffer (Ac)	Comment
4,966	NA	NA	NA		

Notes: [A] Sub-reaches are listed as they occur, going in a downstream direction as indicated by the stationing provided.

Prior to the mitigation project, riparian sections along Puzzle Creek were utilized for pasture and were frequently mowed. Today much of the site is wooded, with acreage being managed for timber production and also as a timberland used for hunting and quite enjoyment. The primary causes of impairment found within the project reaches included previous efforts to channelize the streams, logging activities, an abundance of unstable log jams resulting in erosion, and the presence of non-native vegetation.

The upper reach (reach 1) of the mainstem of Puzzle Creek was severely laterally unstable resulting in the presence of self-perpetuating debris jams. Bank erosion, falling trees, incision, and impingement on the valley wall were considered significant and irreversible trends present in the reach. A combination of Priority I and Priority II Restoration approaches were implemented along Reach 1 based on the need to excavate the floodplain in some areas while in other areas a new channel would be excavated that utilized the existing floodplain. As was the case with all project reaches, unforested sections of floodplain as well as areas of recently disturbed floodplain were seeded and replanted with trees and shrubs native to the area to provide stability and create an adequate riparian buffer.

The reach of Puzzle Creek downstream of the confluence with UT1 (Reach 2) was suffering from a cycle of debris jams, lateral instability, bank erosion, channel avulsion, and falling trees. This section of Puzzle Creek was incised, although some flood relief was available by the presence of a remnant channel in the left floodplain. A combination of Priority I and Priority II Restoration was applied in Reach 2 to create a meandering pattern with stable riffles and pools. This approach resulted in the channel being moved away from the right valley wall and provided marked improvements in the profile, cross-section, and stability of the channel pattern.

Throughout UT1, a combination of Priority I and II Restoration approaches was implemented. Reach 1 of UT1 flows west then northwest from the upstream end of the Schafer property boundary to a break in the easement above the waterfall. The primary issues addressed on UT1 were connectivity of the stream to the floodplain, localized erosion of streambanks and impingement on valley walls, sub-reaches with bed features that are inconsistent with the plan form of the stream, and non-native vegetation. At the uppermost end of the reach, floodplain connectivity was addressed by changing the bed profile, thereby raising the water surface. By creating backwater in meander bends, naturally-sustainable pools were created. Further downstream, a new channel was constructed to bring the stream away from the valley wall and to create more natural riffle-pool sequences. Below this offline section, banks were graded to improve stream stability and create the needed cross-section while following the existing channel course. A riprap stream crossing was installed in this reach for land-owner and forest fire response access to both sides of the creek. Below the crossing, intact banks and bed diversity minimized the meandering needed and restoration consisted of making minor changes to the channel cross-section, pattern and profile as necessary to improve bank stability and sediment transport continuity.

In other less stable sections where the stream exhibited signs of channelization, the channel was taken offline to restore pattern and profile, creating a more stable channel with a more diverse channel bedform. A significant amount of bedrock is present throughout Reach 1. Consequently, the channel was brought back online where bedrock is present.

In other areas, where bedform is diverse, banks stable, and valley constraints present, modifications to the profile and cross-section were made, but the channel was kept in its existing alignment. For these reasons, an Enhancement Level I approach was taken in those sections of Reach 1.

In accordance with the approved mitigation plan for the site, construction activities began in September 2008. Toward the end of construction in October 2008 and shortly thereafter, the project site experienced a series of flood events. Baker evaluated the site to determine the appropriate course of action needed to stabilize the project area. It was determined that damage sustained on Puzzle Creek warranted re-mobilizing a construction crew to the site to repair damage to the site. Minor areas of erosion were stabilized and additional vegetated geolifts were added. Just upstream of the confluence with UT1 one meander was removed to increase the meander length in this area. The last meander on Puzzle was determined to be excessively tight, so the radius was reduced slightly by bringing the meander bend in

slightly and a cross-vane was constructed at the head of the riffle to center the thalwag and hold elevation through the upstream pool.

At that time, UT1 had not been completed. During late fall and winter, a number of subsequent flood events impacted UT1, which had been completed by that time. In early 2009, Baker staff visited the site to assess channel and bank stability. Although there were no areas suffering from excessive erosion, there were some indications that the channel, as constructed, was not functioning to the level desired. Initially it appeared that meanders were attempting to elongate downstream and improper pattern was suspected; however, after some time passed and additional high flows passed through the channel it was determined that the pattern of instability was due to the banks not being established at the proper elevation and the floodplain needing to be lower over a wider area. In early 2010 the channel banks were modified by lowering the banks in some areas and lowering the floodplain elevation to accommodate bank flows. The repaired site has been observed for a number of months and appears to be stabilized by the channel modifications. Further observation has not resulted in any additional design concerns.

Plan modifications during construction involved the location and selection of instream structures and bank stabilization practices as well as the lowering of the bankfull elevation in isolated reaches along Puzzle Creek and UT1. Another modification made included applying Priority I and II measures on two additional tributaries to Puzzle Creek that are located within the project area. Unnamed Tributary 2 (UT2) is located above the confluence of Puzzle Creek and UT1. The third unnamed tributary to Puzzle Creek, UT3, is located just upstream of the only cross-vane on Puzzle Creek and downstream of the confluence with UT1. These tributaries are included in the total Restoration footage due to the need to reconstruct the confluences of these streams as the mainstem was modified. Invasive vegetation removal and replanting of these areas with native riparian vegetation was carried out along these tributaries. The total linear feet of UT2 and UT3 that Restoration measures were applied on is 52 LF and 48 LF, respectively. Restoration measures applied to UT2 and UT3 actually extend beyond the conservation easement boundary, but footage beyond the easement was not considered in calculating the mitigation credit provided by this site. These changes are documented in the attached as-built drawings. The final as-built stream length for the project as indicated in Table 1 is 5,073 LF.

1.3 Project History and Background

The chronology of the Puzzle Creek mitigation project is presented in Table 2 while the contact information for designers, contractors and plant material suppliers is presented in Table 3. Relevant project background information is presented in Table 4. Total stream length across the project increased from approximately 4,849 LF to 5,073LF.

Table 2. Project Activity and Reporting History
Puzzle Creek Mitigation Project-NCEEP Project#92522

Activity or Report	Data Collection	Completion or Delivery
Restoration Plan	October 2007	December 2007
Final Design-90%	October 2007	December 2007
Construction	-	October 2008
Temporary S&E mix applied to entire project area	-	October 2008
Permanent seed mix applied to project site	-	October 2008
Containerized and B&B plantings set out	-	October 2008
Flood Events; Site Repairs	-	October-November 2008
Site Evaluation on UT1	January 2009	-

Site Modifications and Repairs	April 2010	-
Mitigation Plan / As-built (Year 0 Monitoring – baseline)	July 2010	January 2011
Year 1 Monitoring	November 2011; January-February 2012	May 2012
Year 2 Monitoring		
Year 3 Monitoring		
Year 4 Monitoring		
Year 5 Monitoring		

Table 3. Project Contacts Table Puzzle Creek Mitigation Project-NCEEP Project#92522	
Designer	
Michael Baker Engineering, Inc.	797 Haywood Rd Suite 201, Asheville, NC 28806 Contact: Micky Clemmons, Tel. 828.350.1408 x2002
Construction Contractor	
River Works, Inc.	8000 Regency Parkway, Suite 200, Cary, NC 27511 Contact: Will Pedersen, Tel. 919.459.9001
Planting & Seeding Contractor	
River Works, Inc.	8000 Regency Parkway, Suite 200, Cary, NC 27511 Contact: George Morris, Tel. 919.459.9001
Seed Mix Sources	Green Resources
Nursery Stock Suppliers	Arborgen and Hillis Nursery
Monitoring	
Michael Baker Engineering, Inc.	797 Haywood Rd Suite 201, Asheville, NC 28806 Contact: Carmen McIntyre, Tel. 828.350.1408 x2010

Table 4. Project Attribute Table Puzzle Creek Mitigation Project-NCEEP Project#92522	
Project County	Rutherford County, NC
Physiograhic Region	Piedmont Province. Borders Blue Ridge Escarpment
Ecoregion	Southern Inner Piedmont
Project River Basin	Broad
USGS HUC for Project	03050105070050
NCDWQ Sub-basin for Project	03-08-02
Within extent of EEP Watershed Plan?	No
WRC Class	Cool
% of Project Easement Fenced or Demarcated	~5% (goat pasture)

Table 4. Project Attribute Table **Puzzle Creek Mitigation Project-NCEEP Project#92522**	
Beaver Activity Observed During Design Phase?	No
Drainage Area (Square Miles or Acres)	
Puzzle Creek Reach 1	2.58 mi^2
Puzzle Creek Reach 2	4.18 mi^2
UT1Reach 1	1.6 mi^2
UT1 Reach2	1.6 mi^2
UT2	<.5 mi^2
Stream Order	Puzzle-3rd Order, UT1-2nd Order, UT2-1st Order
Restored Length	
Puzzle Creek Reach 1	1,000 LF
Puzzle Creek Reach 2	634 LF
UT1Reach 1	3,339 LF
UT 2	52 LF
UT 3	48 LF
Perennial or Intermittent	Perennial (all project streams)
Watershed Type	Rural (Predominantly Forested)
Watershed LULC Distribution (Percent area)	
Forest	61%
Shrub	12%
Pasture	27%
Water	.45%
Drainage Impervious Cover Estimate (%)	<5%
NCDWQ AU/Index #	9-41-19
303d Listed	No
Upstream of 303d Listed Segment	No
Reasons for 303d Listing or Stressor	-
Total Acreage of Easement	11.64 Acres
Total Vegetated Acreage w/in Easement	n/a (Easement vegetated with exception of stream channel and access path)
Total Planted Acreage within the Easement	~10 Acres
Rosgen Classification (Pre-existing)	
Puzzle Creek Reach 1	C4
Puzzle Creek Reach 2	E4
UT1Reach 1	B4c/C4
UT1 Reach2	B4c

Table 4. Project Attribute Table **Puzzle Creek Mitigation Project-NCEEP Project#92522**				
Rosgen Classification of As-built				
Puzzle Creek Reach 1	E4			
Puzzle Creek Reach 2	E4			
UT1Reach 1	E4/C4			
UT1 Reach2	E4			
Valley Type	VIII			
Valley Slope	.001 to .0106			
Valley Side Slope Range	n/a			
Valley Toe Slope Range	n/a			
Trout Waters Designation	No			
Species of Concern	No			
Dominant Soil Series and Characteristics	Chewacla/ Pacolet/Pacolet-Bethlehem			
	Depth (in.)	% Clay	K Factor	T Factor
Puzzle Creek Reach 1	61”	22.5	.32	5
Puzzle Creek Reach 2	61”	22.5	.32	5
UT1Reach 1	61”	22.5	.32	5
UT1 Reach2	62”	27.5	.2	3

1.4 Monitoring Plan View

A set of plans depicting the monitoring features for the Puzzle Creek Mitigation Project is attached to the monitoring report. The plan set also provides call outs at locations where stream and vegetation problem areas are present. With the exception of intermittent areas of kudzu encroachment and patches of Chinese privet or multiflora rose scattered throughout the project reaches on Puzzle Creek and UT1, there are no additional problems present. These areas with invasive species are being treated to eradicate them if possible. Figure 2 illustrates the project as it is delineated by reach.

LEGEND:

Project Reaches
- Puzzle Creek
- UT2
- UT1
- UT3

Conservation Easement
Cross-sections
Surveyed Profile
Streams

0 100 200 400 Feet

Ecosystem Enhancement Program

Figure 2 Restoration Summary Map

Puzzle Creek Restoration Project

Rutherford County, NC

Baker

2.0 PROJECT CONDITION AND MONITORING RESULTS

The five-year monitoring plan for the Puzzle Creek mitigation project includes criteria to evaluate the success of the vegetation and stream components of the project. The specific locations of vegetation plots, permanent cross-sections, reference photo stations and crest gauges are shown on the Year 1monitoring plan sheets submitted with this report.

2.1 Vegetation Assessment

2.1.1 Vegetation

Successful restoration of the vegetation on a 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, eight vegetation monitoring quadrants were installed across the restoration site. The size of individual quadrants vary 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 of vegetation. Individual seedlings were 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 woody stems and the current year's living, planted stems.

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. Photos of the plots are included in Appendix B of this report.

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 Year 5 of the monitoring period.

Temporary seeding applied to streambanks beneath the erosion matting sprouted within two weeks of application and has provided excellent ground coverage. Live stakes and bare root trees planted are also flourishing and will increasingly contribute to streambank stability. Bare-root trees were planted throughout the conservation easement. A minimum 30-foot buffer was established along all restored stream reaches. In general, bare-root vegetation was planted at a target density of 680 stems per acre, in an 8-foot by 8-foot grid pattern. Planting of bare-root trees was completed in the winter of 2009-2010. Species planted are listed below.

Table 5. Riparian Buffer Planting List Puzzle Creek Mitigation Plan-NCEEP Project #92522			
Proposed Bare-Root and Live Stake Species (may also include seed or container species)			
Common Name	**Scientific Name**	**% Planted by Species**	**Planting Density**
Riparian Buffer Plantings			
Trees Overstory			
Sycamore	*Platanus occidentalis*	20%	136
Willow Oak	*Quercus phellos*	7%	48
River birch	*Betula nigra*	15%	102
Persimmon	*Diospyros virginiana*	10%	68
Alternate Species			
Tulip Poplar	*Liriodendron tulipifera*	20%	136
Green Ash	*Fraxinus pennsylvanica*	15%	102
Swamp Chestnut Oak	*Quercus michauxii*	8%	54
Black Cherry	*Prunus seritona*	5%	34
Understory Trees/Shrubs			
Pawpaw	*Asimina triloba*	15%	102
Witch-hazel	*Hamamelis virginiana*	15%	102
Spicebush	*Lindera benzoin*	20%	136
Alternate Species			
Sweet Shrub	*Calycanthus floridus*	15%	102
Redbud	*Cercis canadensis*	10%	68
Flowering Dogwood	*Cornus floridus*	15%	102
Arrowwood Viburnum	*Viburnum dentatum*	10%	68
Riparian Livestake Plantings			
Ninebark	*Physocarpus opulifolius*	na	
Elderberry	*Sambucus canadensis*	na	
Silky Willow	*Salix sericea*	na	
Silky Dogwood	*Cornus amomum*	na	
Note: Species selection may have changed due to refinement or availability at the time of planting.			

2.1.2 Soil Data

Table 6. Preliminary Soil Data **Puzzle Creek Mitigation Project-NCEEP Project #92522**					
Dominant Soil Series and Characteristics	Chewacla/ Pacolet/Pacolet-Bethlehem				
	Depth (in.)	% Clay	K Factor	T Factor	%OM
Puzzle Creek Reach 1	61”	22.5	.32	5	.75-2.5
Puzzle Creek Reach 2	61”	22.5	.32	5	.75-2.5
UT1Reach 1	61”	22.5	.32	5	2-2.5
UT1 Reach2	62”	27.5	.2	3	2-2.5

2.1.3 Vegetative Problem Areas

There are no major vegetation problem areas at this time. However, Chinese privet (*Ligustrum sinense*) is scattered intermittently in areas on-site as is kudzu, which is primarily encroaching upon the easement area on the lower end of Reach 2 of Puzzle Creek as well as the up stream end of UT1 (Table 8, Appendix B). The planting and seeding contractor for the Site has been notified and is scheduled to treat areas where invasive vegetation is present during this summer.

2.1.4 Stem Counts

The mitigation plan for the Puzzle Creek Site specifies that the number of quadrants required will be based on the species/area curve method, as described in NCEEP monitoring guidance documents. The size of individual quadrants is 100 square meters for woody tree species, and 1 square meter for herbaceous vegetation. Eight vegetation plots, each 10 by 10 meters or 5 by 20 meters in size, were established across the restored site.

2.1.4.1.1 Results

Table 7 in Appendix A presents information on the stem counts for each of the vegetation monitoring plots. Data from the Year 1 monitoring event showed a range of 445-809 planted stems per acre, with approximately 94% of the stems showing no signs of damage. The average density of planted bare root stems, based on data collected from the eight monitoring plots during Year 1 monitoring, is 632 stems per acre which indicates that the Site is on track for meeting the minimum success interim criteria of 320 trees per acre by the end of Year 3 and the final success criteria of 260 trees per acre by the end of Year 5. The locations of the vegetation plots are shown on the Year 1 monitoring plan sheets.

No woody or herbaceous vegetation problem areas were identified during Year 1 monitoring. Although the density of herbaceous cover varies across the site, conditions observed on-site during the Year 1 monitoring survey found ground cover in the easement area to be sufficient for aiding in site stabilization. Survival rates of planted woody stems in the vegetation plots indicate that plantings across the easement area are of sufficient density to meet regulatory requirements, as well as the site stabilization and habitat enhancement goals originally set forth in the mitigation plan.

2.2 Stream Assessment

2.2.1 Morphologic Parameters and Channel Stability

Geomorphic monitoring of restored stream reaches is being conducted over a five year period to evaluate the effectiveness of the restoration practices installed. Monitored stream parameters include channel dimension (cross-sections), profile (longitudinal survey), pattern, bed composition, bank stability, bankfull flows, and stability of reference sites documented by photographs. Crest gauges, as well as wrack lines, will be used to document the occurrence of bankfull or greater events. The methods used and any related success criteria are described below for each parameter. For monitoring this site, twelve permanent cross-sections and two crest gauges were installed. Longitudinal profiles were also completed on Puzzle Creek, UT1 and UT2. Detailed channel morphology was surveyed with a total station by Baker under the direction of Will Kent, PLS; survey data is georeferenced.

2.2.1.1 Dimension

Twelve permanent cross-sections were installed to help evaluate the success of the mitigation project. Permanent cross-sections were established throughout the project site as follows: five cross-sections were located on Puzzle Creek, and six cross-sections were located on

UT1. One cross-section was also located on UT2 to monitor restoration efforts associated with riparian improvements, pattern and profile adjustments made at the confluence of UT2 and Puzzle Creek. Cross-sections selected for monitoring were located in representative riffle and pool reaches and each cross-section was marked on both banks with permanent pins to establish the exact transect used. 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 all breaks in slope, including top of bank, bankfull, edge of water, and thalweg, if the features are present. Riffle cross-sections were classified using the Rosgen Stream Classification System.

There should be little change in the as-built cross-sections. If changes do take place, they will be evaluated to determine if they represent movement toward a more unstable condition (e.g., down-cutting or erosion) or movement toward increased stability (e.g., settling, vegetative changes, or deposition along the banks).

2.2.1.1.1 Results

As-built cross-section monitoring data for stream stability was collected in January and February 2011. The twelve permanent cross-sections along the restored channels were re-surveyed in January and February 2012 to document stream dimension for Monitoring Year 1. Cross-sectional data is presented in Table 13 (Appendix B) and the location of cross-sections is shown on the plan sheets submitted with this report.

The cross-sections show that there has been little to no adjustment to stream dimension across the project reaches since construction. At this time, cross-sectional measurements do not indicate any streambank or channel stability issues.

2.2.1.2 Pattern and Longitudinal Profile

Longitudinal profiles for Year 1 were also surveyed during January and February 2012; profiles of the various project reaches are provided in Appendix B. A longitudinal profile was conducted for the entire project length on Puzzle Creek, UT2, UT3, and 3,000 LF of UT3. Longitudinal profiles will be replicated annually during the five year monitoring period.

Measurements taken during longitudinal profiles include thalweg, water surface, and the left and right top of bank. 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. Profile data collected reflect stable channel bedform and a diverse range of riffle and pool complexes.

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. Puzzle Creek and its tributaries are C-type streams primarily characterized by step-pool sequences. Consequently, pattern information is not provided in Appendix B as the parameters present are generally associated with meandering, riffle-pool channels. However, as the site is monitored, reaches will be evaluated for significant changes in pattern. Any changes that warrant repair will be discussed in future monitoring reports.

2.2.1.2.1 Results

The longitudinal profiles show that the bed features are stable. As noted in the Stream Reach Morphology Data Tables in Appendix B (Table 14), riffle and pool characteristics do not appear to have changed much since construction; the measurements obtained for Year 1 are acceptable when compared to reference reach and design data provided for the project

reaches. There was also little to no change in the profile of UT1 to Puzzle Creek. No areas of instability were noted during Year 1 monitoring.

2.2.1.3 Substrate and Sediment Transport

Bed material analysis consists of a pebble count taken in the same constructed riffle during annual geomorphic surveys of the project site. This sample, combined with evidence provided by changes in cross-sectional 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.

2.2.1.3.1 Results

For this project, a pebble count was collected on UT1. Visual observations and a review of pebble count data collected during Year 1 monitoring did not yield any signs that sediment transport functions have been hampered by the mitigation project; specifically, no significant areas of aggradation or degradation within the project area were observed. The pebble count data (Appendix B) indicates that the stream is moving fines through the system though there is yet to be a marked trend in larger pebbles making up a greater percentage of the bed material.

2.2.2 Hydrology

2.2.2.1 Streams

The occurrence of bankfull events within the monitoring period will be documented by the use of crest gauges and photographs. Crest gauges were installed on the floodplain at bankfull elevation. One crest gauge was set up near Vegetation Plot #3 on UT1 while another gauge was set up near the first two cross-sections in Reach 1 of Puzzle Creek. 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 wrack lines and sediment deposition on the floodplain during monitoring site visits.

Two bankfull flow events must be documented on each 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.

2.2.2.1.1 Results

During the spring of the Year 1 monitoring period, the site was found to have had at least one bankfull event based on crest gauge readings obtained on UT1 and Puzzle Creek. Information on these events is provided in Table 9 of Appendix B.

2.2.3 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.

2.2.3.1 Lateral Reference Photos

Reference photo transects were taken of the right and left banks at each permanent cross-section. A survey tape was captured in most photographs which 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.

2.2.3.2 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. Photo documentation of the site during Year 1 monitoring reflects stable site conditions in restored or enhanced areas as well as a healthy stand of herbaceous and woody vegetation in the riparian corridors.

2.2.4 Stream Stability Assessment

In-stream structures installed within the restored streams included cover logs, rootwads, rock vanes, log vanes, and boulder toe protection. The Year 1 visual observations of these structures throughout the project site indicate that little or no changes have occurred since the baseline survey was performed; structures are functioning as designed and are holding their elevation and grade. The Categorical Stream Feature Visual Stability Assessment and Visual Morphological Stability Assessment tables in Appendix B (Tables 11 and 12), summarize the condition of project structures.

Quantitative reference reach and design data used to determine the restoration approach, as built data, as well as Year 1 monitoring data are summarized in Tables 13 and 14 of Appendix B.

2.3 Areas of Concern

At this time, there are no areas of concern. Maintenance of the site for invasive vegetation control is being addressed. The planting and seeding contractor has been notified of the need for invasives treatment, and a site visit to remove and/or spray the vegetation is scheduled for this summer.

3.0 REFERENCES

Leopold, L.B., M. Wolman, and J. Miller. 1964. "Fluvial Processes in Geomorphology." W. H. Freeman, San Francisco, CA.

Peet, R.K., T.R. Wentworth and P.S. White. 1998. "A flexible, multipurpose method for recording vegetation composition and structure." Castanea 63:262-274.

APPENDIX A

VEGETATION RAW DATA

1. VEGETATION SURVEY DATA TABLES
2. VEGETATION MONITORING PLOT PHOTOS

Table 7. Stem Count Arranged by Plot- Year 1
Puzzle Creek Mitigation Site Project #92522

Tree Species	Common Name	Type	Current Data (Yr 1 2011)								AB (2010) Totals	MY (2011) Totals	MY2 (2012) Totals	MY3 (2013) Totals	MY4 (2014) Totals	MY5 (2015) Totals	Survival %	Probable Cause
			Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8								
Betula nigra	River Birch	Tree			1				2	2	2	5					100%	
Diospyros virginiana	American Persimmon	Tree	2	2	2	4	2	1	2	4	19	19					100%	
Fraxinus pennsylvanica	Green Ash	Tree		4	4		4	1	1		17	14					82%	
Liriodendron tulipfera	Tulip Poplar	Tree		4	3	3				1	11	11					100%	
Platanus occidentalis	American Sycamore	Tree	1	1		10	3	3	5	2	27	25					93%	
Prunus serrulata	Black Cherry	Tree							4		5	4					80%	
Quercus coccinea	Scarlet Oak	Tree									1	0					0%	Re-ID'ed as Q. rubra as it has grown
Quercus falcata	Southern Red Oak	Tree									2	0					0%	Re-ID'ed as Q. rubra as it has grown
Quercus michauxii	Swamp Chestnut Oak	Tree	1					3	1	3	10	8					80%	
Quercus phellos	Willow Oak	Tree	6				1	4		2	18	13					72%	Beaver; outcompeted by surrounding veg.
Quercus rubra	Northern Red Oak	Tree	2	2				2	1	1	5	8					100%	
Salix nigra	Black Willow	Tree		1						1	3	2					67%	Damaged during over-bkf storm event
Understory Species																		
Alnus serrulata	Tag Alder	Tree	2			1	1	3	3		12	10					83%	
Asimina triloba	Pawpaw	Tree			1						2	1					50%	unknown
Cercis canadensis	Redbud	Tree				2					2	2					100%	
Cornus floridus	Flowering Dogwood	Tree			1					2	7	3					43%	Damaged during over-bkf storm event; others possibly weakended by fungus
Volunteers																		
Betula nigra	River Birch	Tree	5	7	1	25	13	2	20	1	87+	87+					100%	
Liriodendron tulipfera	Tulip Poplar	Tree							2	1	1+	3					100%	
Liquidambar styraciflua	Sweet Gum	Tree						8	9			17					100%	
Platanus occidentalis	American Sycamore	Tree	5		11	1	2	20	15	2	25+	56					100%	
Quercus rubra	Northern Red Oak	Tree							1		45+	45+					100%	
	Plot area (acres)		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025							**Averages**	
	Species Count		7	7	7	6	6	9	10	9							8	
	Planted Stems/Plot		14	14	12	20	11	17	19	18							16	
	Stems/Plot		24	21	24	46	26	47	66	22							35	
	Planted Stems Per Acre		567	567	486	809	445	688	769	728							632	

Table 8. Vegetation Problem Areas
Puzzle Creek Mitigation Project: Project No. 92522

Puzzle Creek Reach 1 (1,000 LF)			
Feature Issue	**Station No./Range**	**Suspected Cause**	**Photo Number**
Other	N/A	N/A	N/A
Bare Bank	N/A	N/A	N/A
Bare Bench	N/A	N/A	N/A
Bare Flood Plain	N/A	N/A	N/A
Invasive/Exotic Populations	Intermittently Scattered Throughout	Ligustrum sinense -source outside easement and persisting after treatment	N/A[1]
Puzzle Creek Reach 2 (634 LF)			
Feature Issue	**Station No.**	**Suspected Cause**	**Photo Number**
Other	N/A	N/A	N/A
Bare Bank	N/A	N/A	N/A
Bare Bench	N/A	N/A	N/A
Bare Flood Plain	N/A	N/A	N/A
Invasive/Exotic Populations	Intermittently Scattered Throughout	Kudzu-source outside easement near Veg Plot 8, Ligustrum sinense -source outside easement and persisting after treatment	N/A[1]
UT1 (3,339 LF)			
Feature Issue	**Station No.**	**Suspected Cause**	**Photo Number**
Other	N/A	N/A	N/A
Bare Bank	N/A	N/A	N/A
Bare Bench	N/A	N/A	N/A
Bare Flood Plain	N/A	N/A	N/A
Invasive/Exotic Populations	Intermittently Scattered Throughout	Kudzu-source outside easement, Ligustrum sinense -source outside easement and persisting after treatment	N/A[1]

Notes: 1. Photos will be taken before and after scheduled treatment in Summer 2012 and provided in MY2 Report.

Puzzle Creek Restoration Project
Photo Log - Vegetation Plot Photo Points

Notes:

1. Photo point locations are shown on the plan views in the actual location the picture was taken.
2. All points are marked with a wooden stake and pink flagging tape.

10/17/2011

Photo 1: Veg Plot 1

10/17/2011

Photo 2: Veg Plot 1: Herbaceous Plot

10/17/2011

Photo 3: Veg Plot 2

10/17/2011

Photo 4: Veg Plot 2: Herbaceous Plot

10/17/2011

Photo 5: Veg Plot 3

10/17/2011

Photo 6: Veg Plot 3: Herbaceous Plot

Puzzle Creek Restoration Project
Photo Log - Vegetation Plot Photo Points

Notes:

1. Photo point locations are shown on the plan views in the actual location the picture was taken.
2. All points are marked with a wooden stake and pink flagging tape.

10/17/2011

Photo 7: Veg Plot 4

10/17/2011

Photo 8: Veg Plot 4: Herbaceous Plot

10/17/2011

Photo 9: Veg Plot 5

10/17/2011

Photo 10: Veg Plot 5: Herbaceous Plot

10/17/2011

Photo 11: Veg Plot 6

10/17/2011

Photo 12: Veg Plot 6: Herbaceous Plot

Puzzle Creek Restoration Project
Photo Log - Vegetation Plot Photo Points

Notes:

1. Photo point locations are shown on the plan views in the actual location the picture was taken.
2. All points are marked with a wooden stake and pink flagging tape.

10/17/2011

Photo 13: Veg Plot 7

10/17/2011

Photo 14: Veg Plot 7: Herbaceous Plot

10/17/2011

Photo 15: Veg Plot 8

10/17/2011

Photo 16: Veg Plot 8: Herbaceous Plot

APPENDIX B

1. HYDROLOGICAL (BANKFULL) VERIFICATIONS (TABLE 9)
2. STREAM PROBLEM AREAS (TABLE 10)
3. CROSS-SECTION PLOTS WITH ANNUAL OVERLAYS
4. LONGITUDINAL PROFILES WITH ANNUAL OVERLAYS
5. CATEGORICAL STREAM FEATURE VISUAL STABILITY ASSESSMENT (TABLE 11)
6. VISUAL MORPHOLOGICAL STABILITY ASSESSMENT (TABLE 12)
7. STREAM REACH MORPHOLOGY AND HYDRAULIC DATA (TABLE 13)
8. CROSS-SECTION MORPHOLOGY AND HYDRAULIC DATA (TABLE 14)
9. RIFFLE PEBBLE COUNT SIZE CLASS DISTRIBUTIONS
10. STREAM REFERENCE STATION PHOTO LOGS

Table 9. Verification of Bankfull or Greater than Bankfull Events
Puzzle Creek Restoration Project No. 92522

Date of Data Collection	Date of Event	Method of Data Collection	Gauge Watermark (inches above bankfull)	
			Puzzle Cr. Reach 1	UT1
2/3/2012	Between January 2011 and 2/2/12	Gauge measurement	2.52"	2.28"

Table 10. Stream Problem Areas
Puzzle Creek Mitigation Project: Project No. 92522

Puzzle Creek Reach 1 (1,000 LF)			
Feature Issue	**Station No.**	**Suspected Cause**	**Photo Number**
N/A	N/A	N/A	N/A
Puzzle Creek Reach 2 (634 LF)			
Feature Issue	**Station No.**	**Suspected Cause**	**Photo Number**
N/A	N/A	N/A	N/A
UT1 (3,339 LF)			
Feature Issue	**Station No.**	**Suspected Cause**	**Photo Number**
N/A	N/A	N/A	N/A

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	40.8	18.43	2.21	3.12	8.32	1	4.3	882.75	882.75

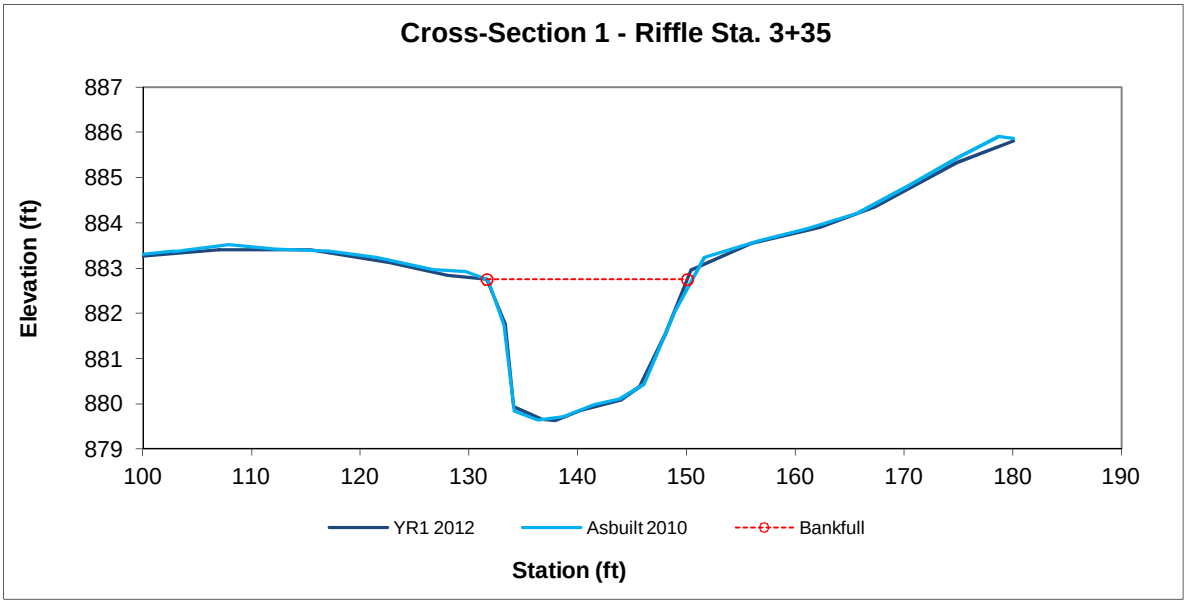


Photo 1: XS-1 facing right bank

Photo2: XS-1 facing left bank

Photo 3: XS-1 facing upstream

Photo 4: XS-1 facing downstream

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	E	62.1	24.1	2.58	4.9	9.35	1	3.9	882.11	882.11

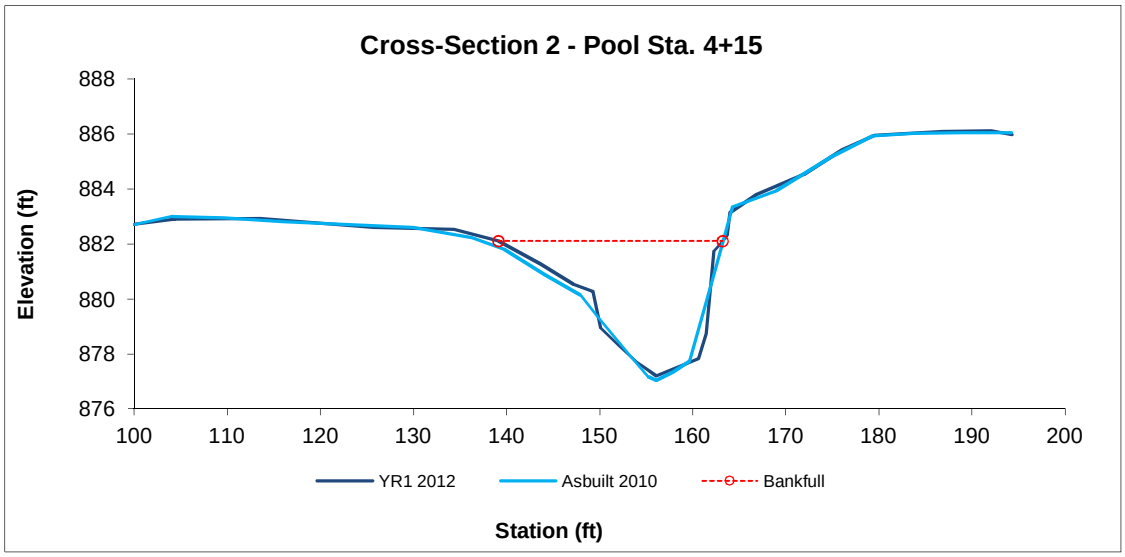


Photo 5: XS-2 facing right bank

Photo 6: XS-2 facing left bank

Photo 7: XS-2 facing upstream

Photo 8: XS-2 facing downstream

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	43.4	17.66	2.46	3.24	7.19	1	3.7	880.34	880.34

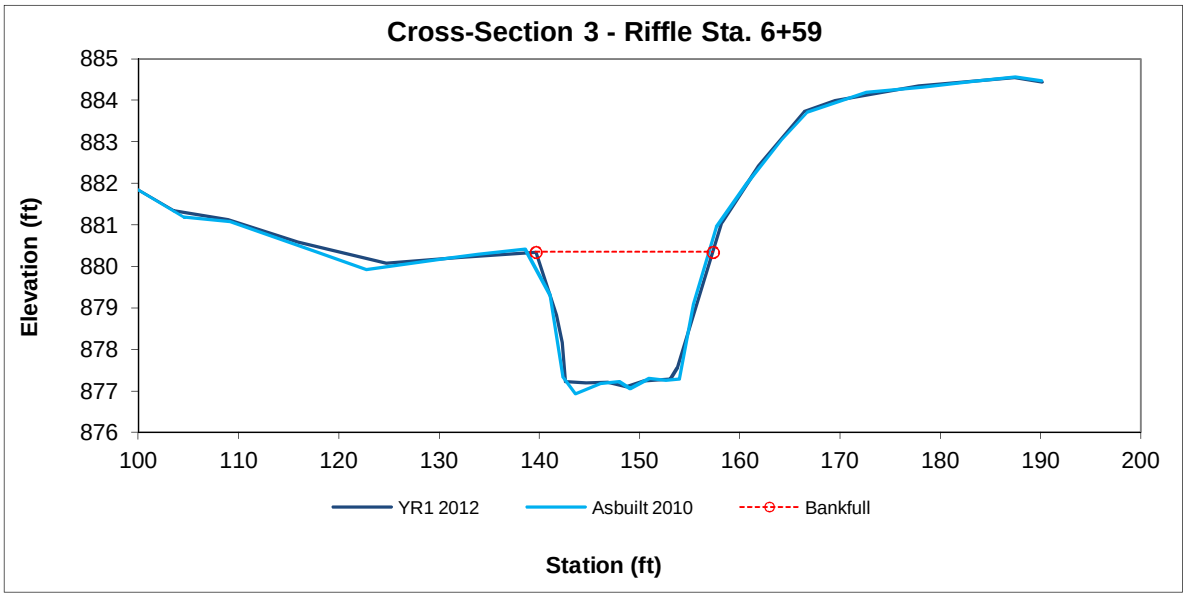


Photo 9: XS-3 facing right bank

Photo 10: XS-3 facing left bank

Photo 11: XS-3 facing upstream

Photo 12: XS-3 facing downstream

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	66.1	26.55	2.49	3.66	10.66	1	3.2	876.04	876.04

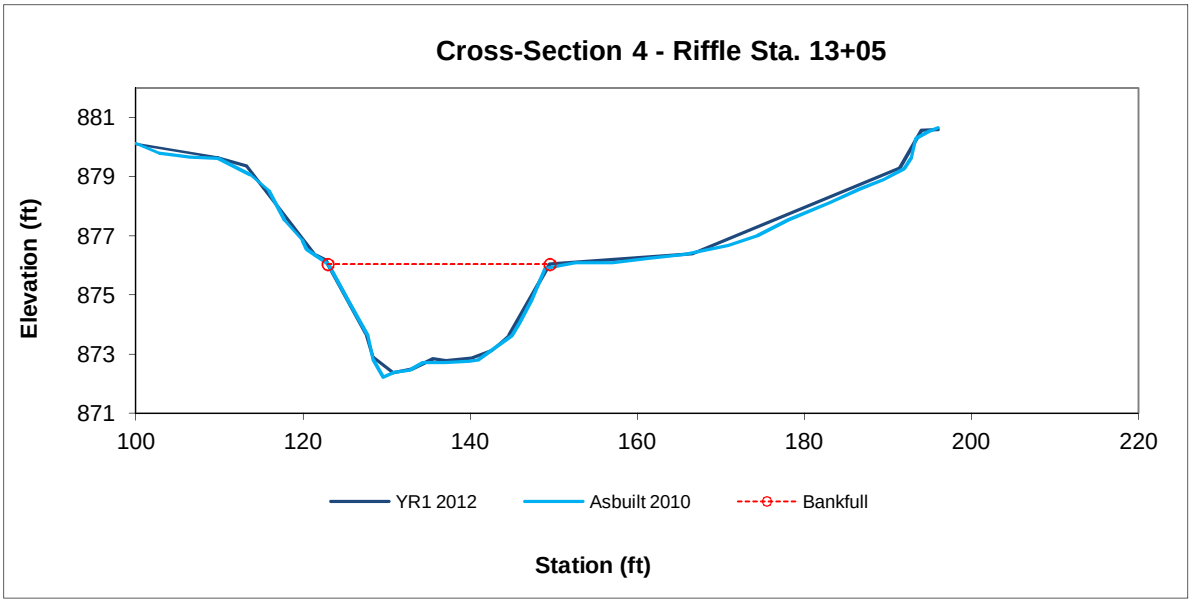


Photo 13: XS-4 facing right bank

Photo 14: XS-4 facing left bank

Photo 15: XS-4 facing upstream

Photo 16: XS-4 facing downstream

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	C	105.8	34.73	3.05	6.33	11.4	1	1.8	874.93	874.93

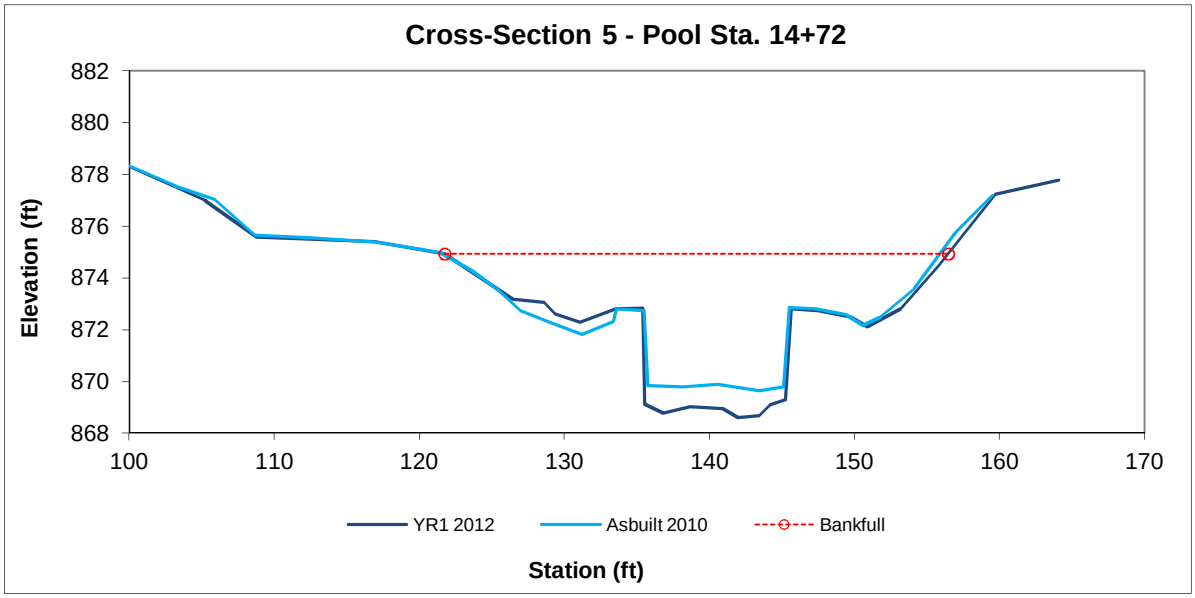


Photo 17: XS-5 facing right bank

Photo 18: XS-5 facing left bank

Photo 19: XS-5 facing upstream

Photo 20: XS-5 facing downstream

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	E	15.9	10.73	1.48	2.72	7.26	1.1	2.7	883.8	884.18

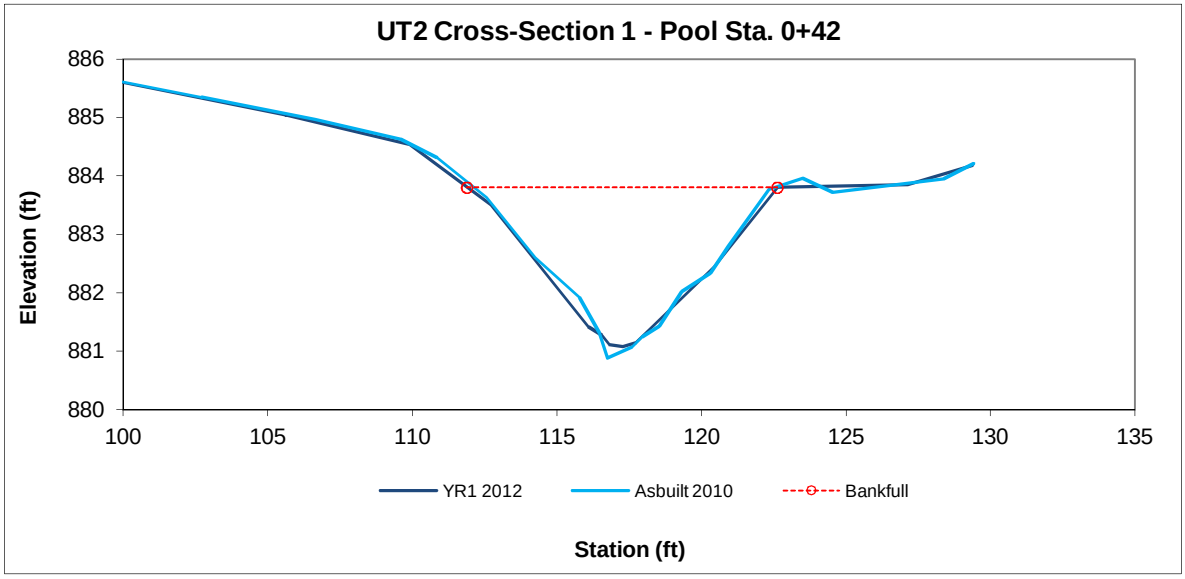


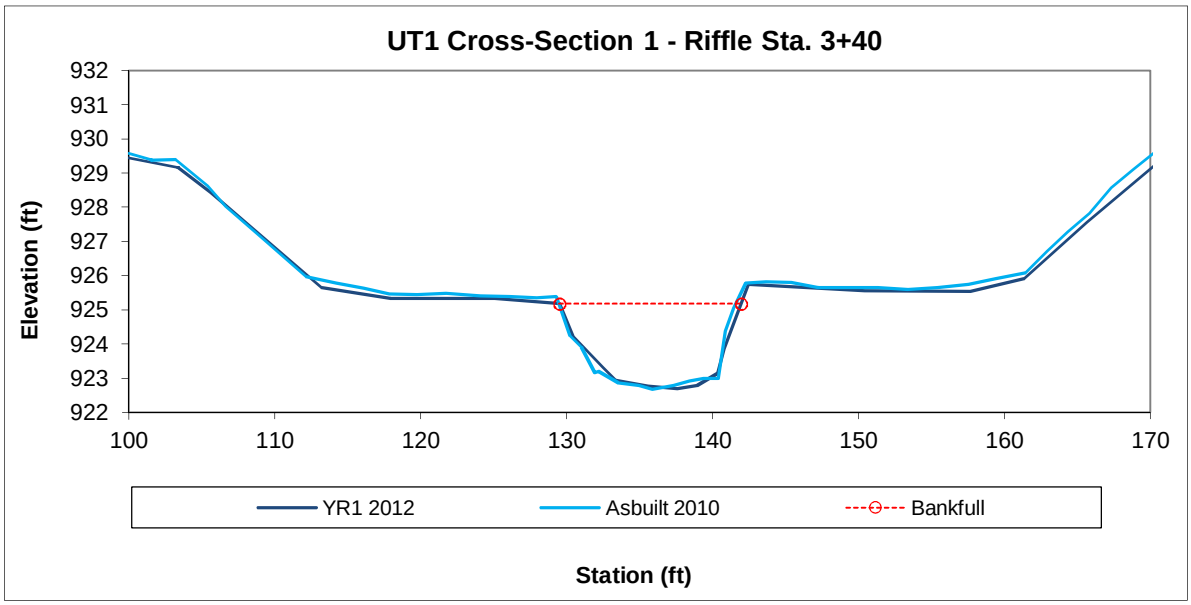
Photo 21: UT2 XS-1 facing right bank

Photo 22: UT2 XS-1 facing left bank

Photo 23: UT2 XS-1 facing upstream

Photo 24: UT2 XS-1 facing downstream

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	23.1	12.45	1.85	2.48	6.72	1	4.7	925.17	925.17



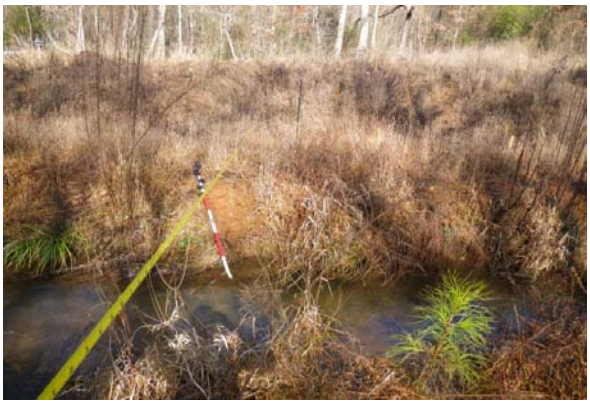


Photo 25: UT1 XS-1 facing right bank

Photo 26: UT1 XS-1 facing left bank

Photo 27: UT1 XS-1 facing upstream

Photo 28: UT1 XS-1 facing downstream

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	33.8	20.23	1.67	2.42	12.12	1	3.8	919.18	919.18

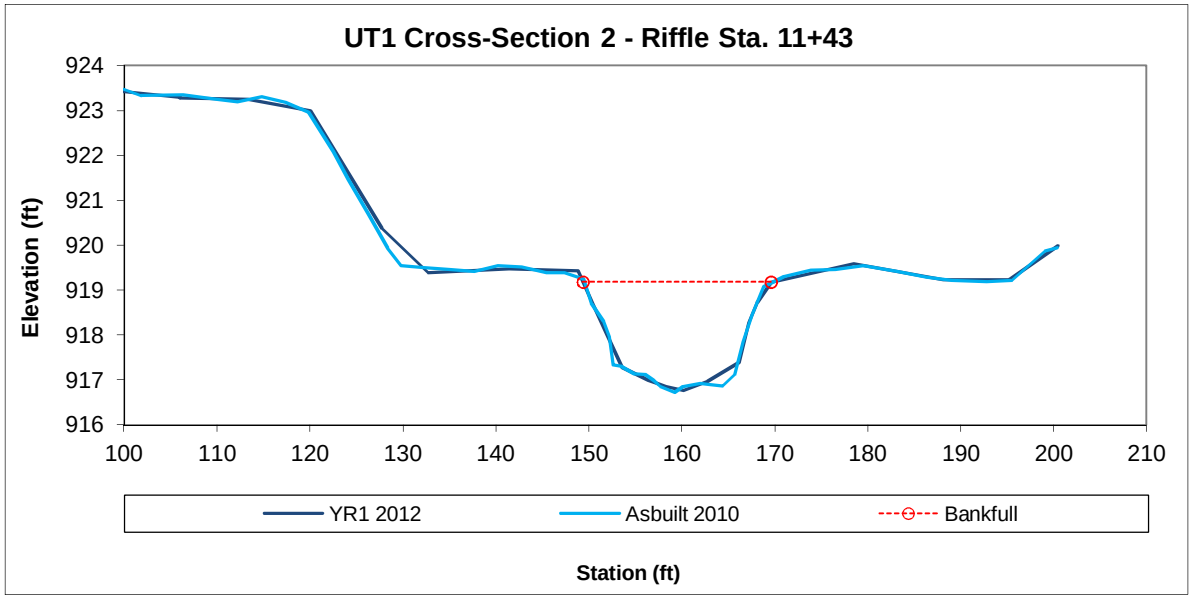


Photo 29: UT1 XS-2 facing right bank

Photo 30: UT1 XS-2 facing left bank

Photo 31: UT1 XS-2 facing downstream

Photo 32: UT1 XS-2 facing upstream

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	C	36.4	27.36	1.33	2.87	20.59	1	2.7	918.57	918.57

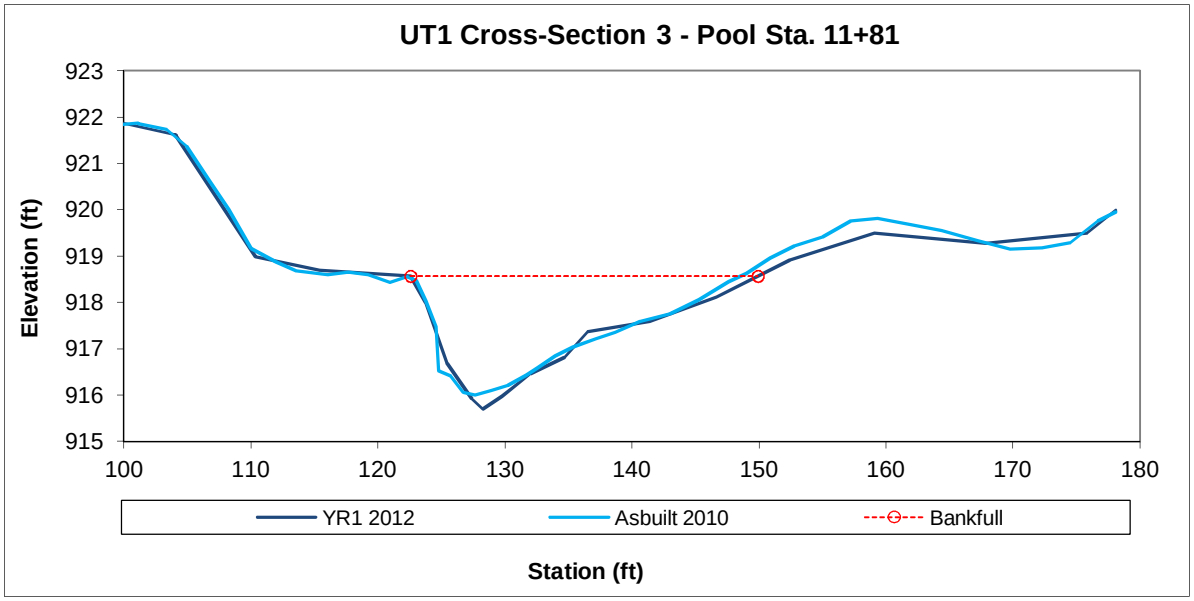


Photo 33: UT1 XS-3 facing right bank

Photo 34: UT1 XS-3 facing left bank

Photo 35: UT1 XS-3 facing upstream

Photo 36: UT1 XS-3 facing downstream

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	C	30.8	20.05	1.54	2.4	13.04	1	2.7	913.2	913.2

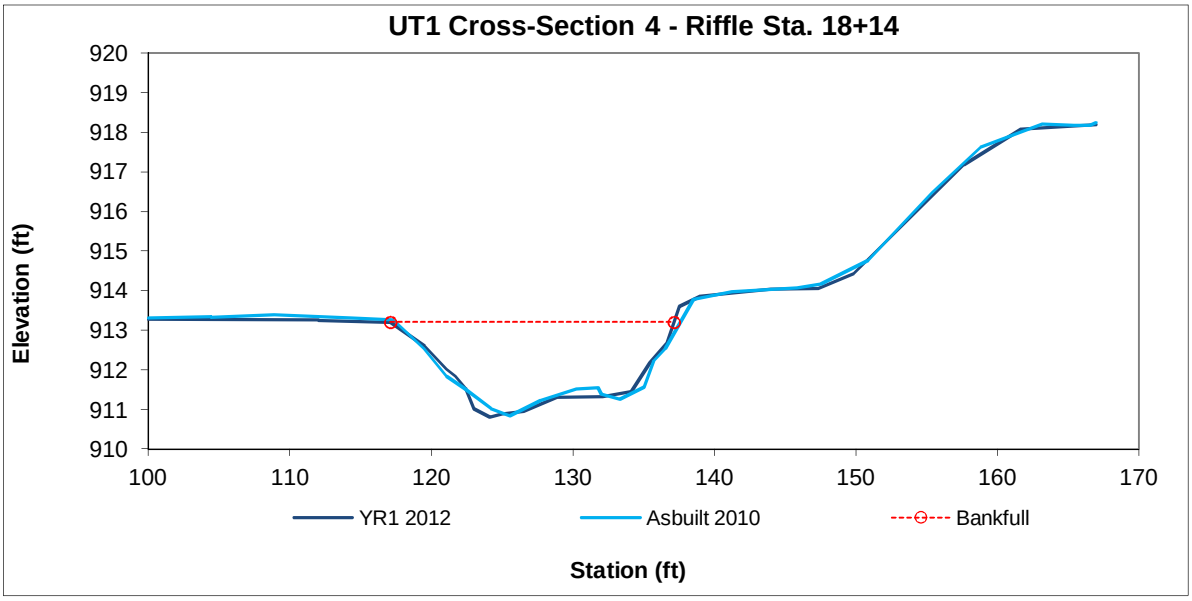


Photo 37: UT1 XS-4 facing right bank

Photo 38: UT1 XS-4 facing left bank

Photo 39: UT1 XS-4 facing upstream

Photo 40: UT1 XS-4 facing downstream

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	C	52.3	27.58	1.9	5.38	14.55	0.7	2.4	913.35	911.57

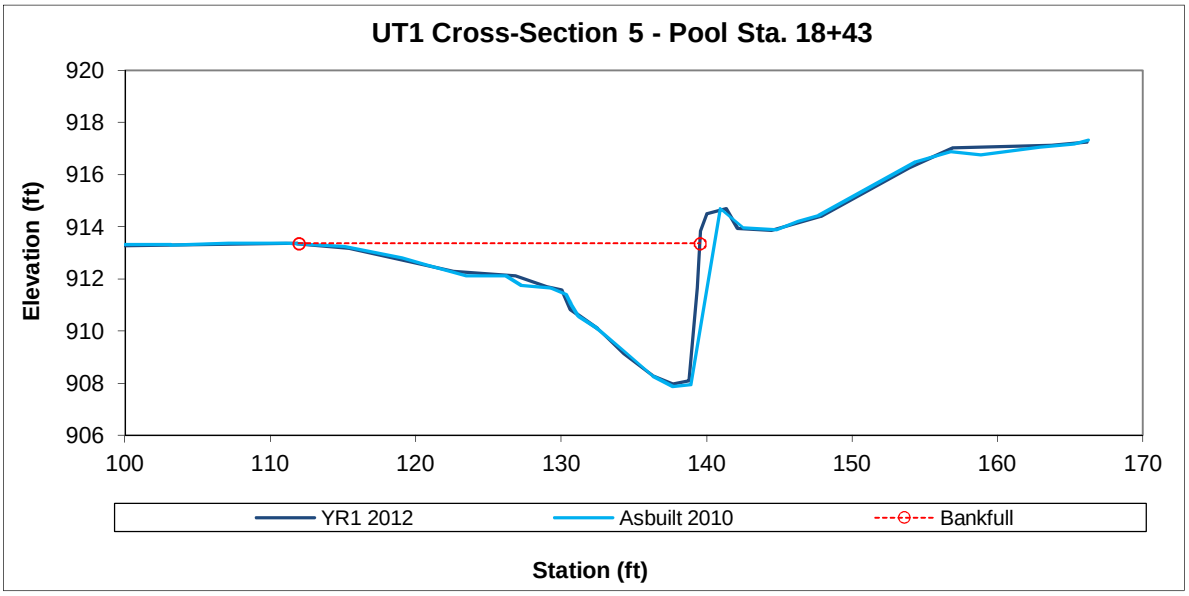


Photo 41: UT1 XS-5 facing right bank

Photo 42: UT1 XS-5 facing left bank

Photo 43: UT1 XS-5 facing upstream

Photo 44: UT1 XS-5 facing downstream

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	C	24.2	14.9	1.62	3.26	9.18	1	2.8	903.58	903.58

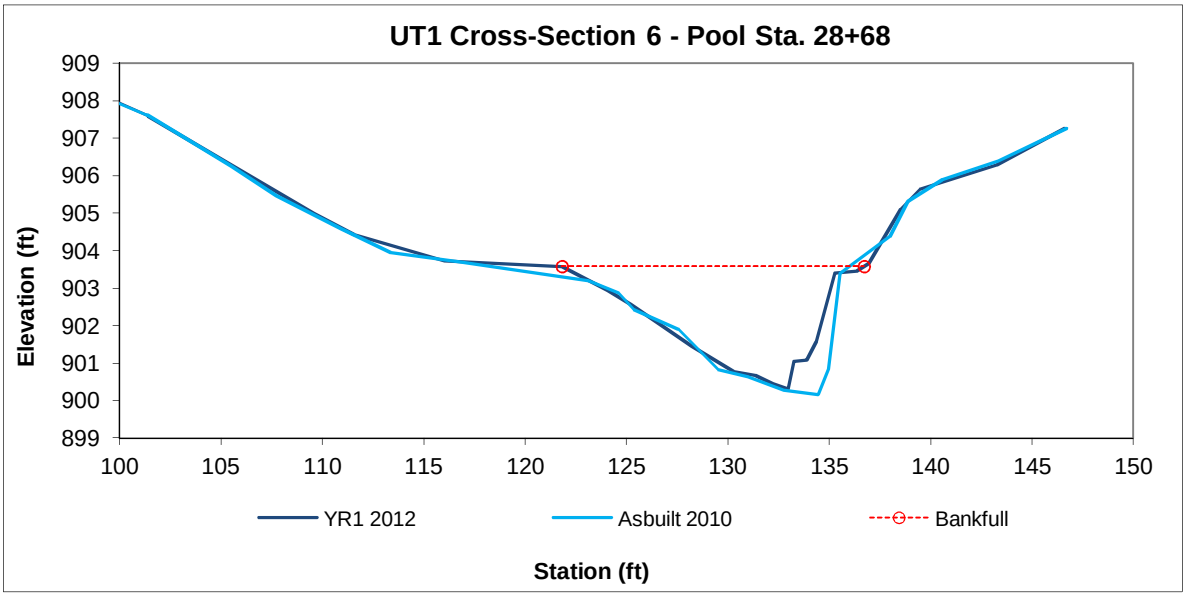
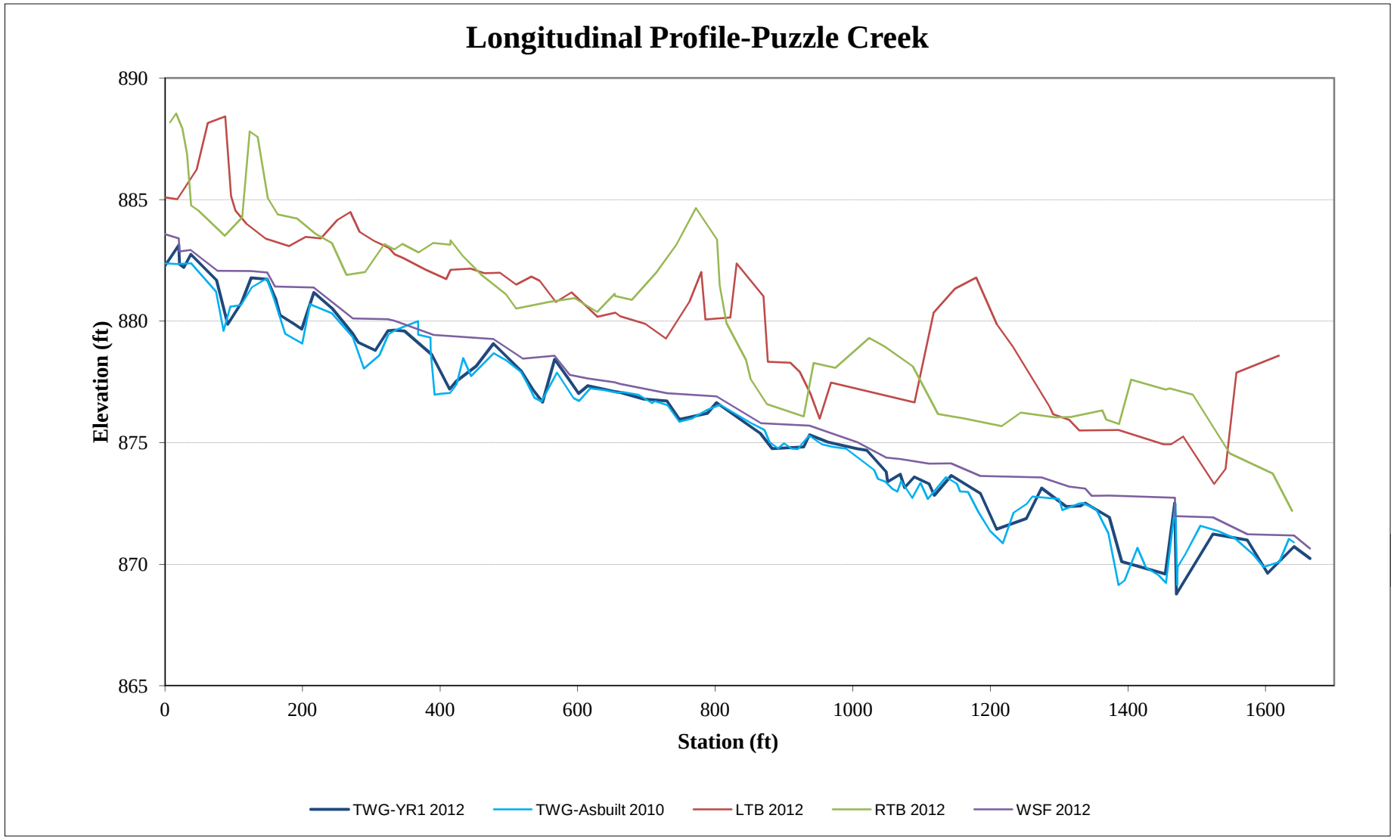


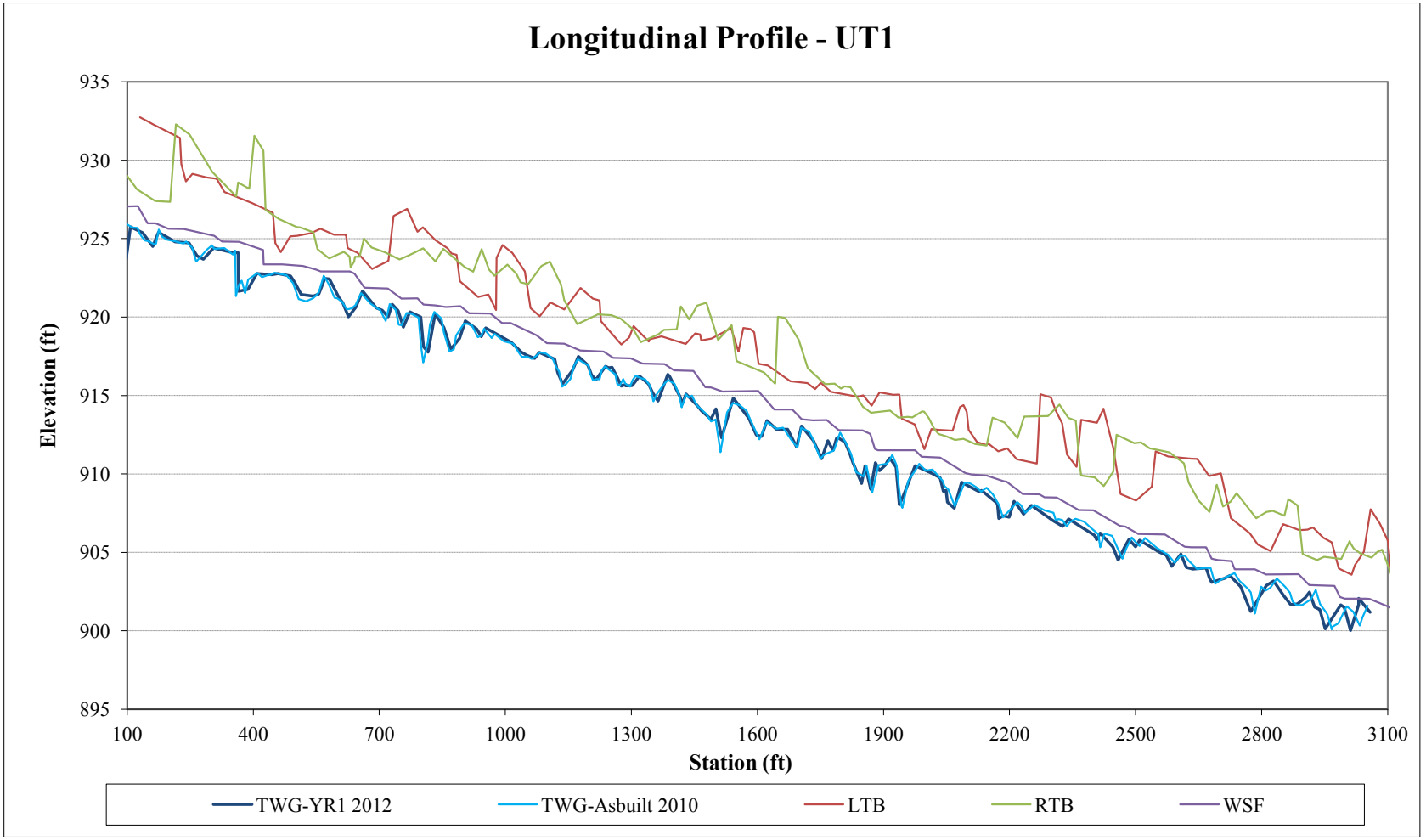
Photo 45: UT1 XS-6 facing right bank

Photo 46: UT1 XS-6 facing left bank

Photo 47: UT1 XS-6 facing upstream

Photo 48: UT1 XS-6 facing downstream


Longitudinal Profile-Puzzle Creek
890
885
880
875
870
865
Elevation (ft)
0
200
400
600
800
1000
1200
1400
1600
Station (ft)
TWG-YR1 2012
TWG-Asbuilt 2010
LTB 2012
RTB 2012
WSF 2012


Longitudinal Profile - UT1
Elevation (ft)
935
930
925
920
915
910
905
900
895
100
400
700
1000
1300
1600
1900
2200
2500
2800
3100
Station (ft)
TWG-YR1 2012
TWG-Asbuilt 2010
LTB
RTB
WSF

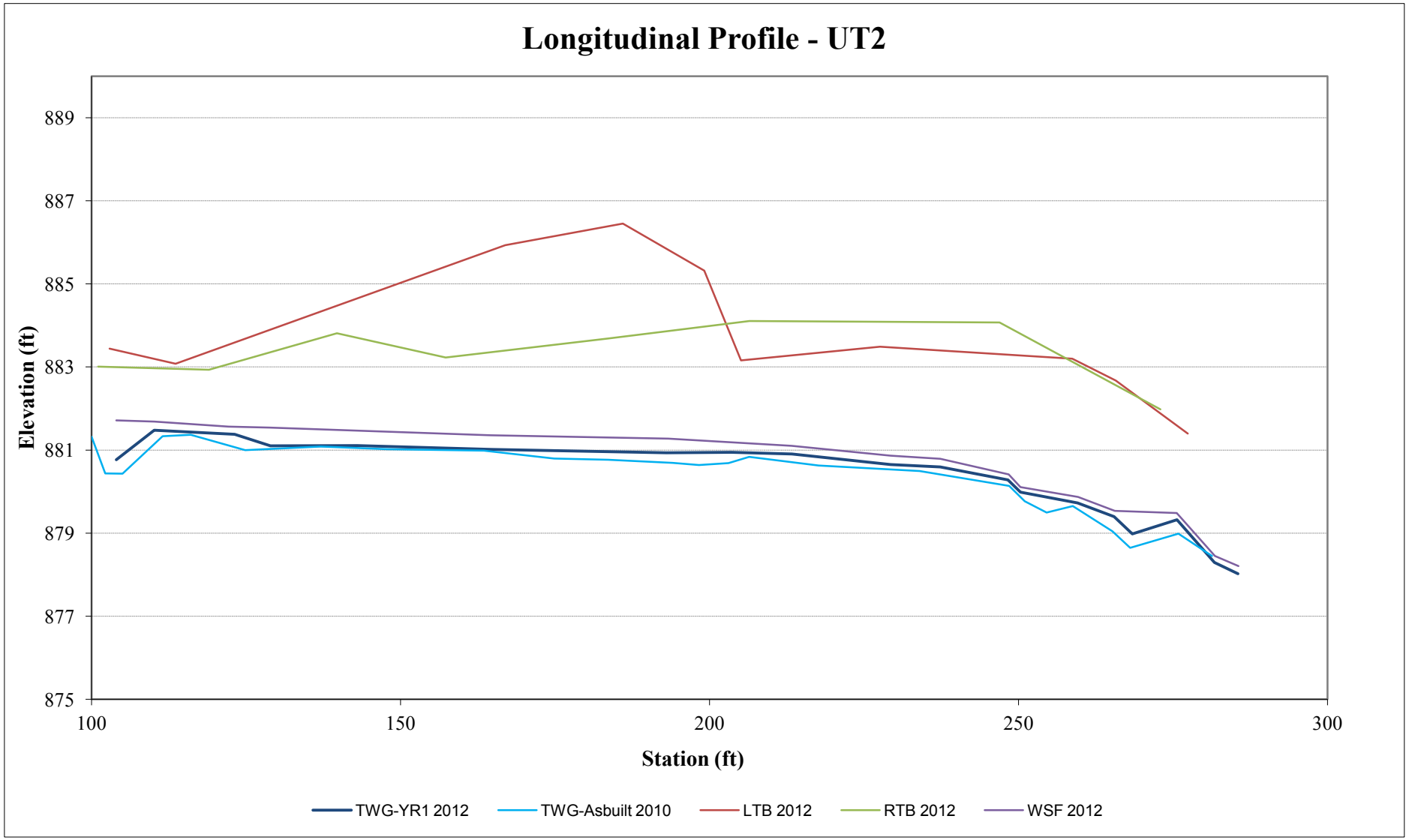

Longitudinal Profile - UT2
Elevation (ft)
889
887
885
883
881
879
877
875
100
150
200
250
300
Station (ft)
TWG-YR1 2012
TWG-Asbuilt 2010
LTB 2012
RTB 2012
WSF 2012

Table 11. Categorical Visual Morphological Stability Assessment						
Puzzle Creek Mitigation Project: Project No. 92522						
Puzzle Creek Reach 1 (1,000 LF)						
Feature	**Initial**	**MY-01**	**MY-02**	**MY-03**	**MY-04**	**MY-05**
Riffles	100%	100%				
Pools	100%	100%				
Thalweg	100%	100%				
Meanders	100%	100%				
Bed General	100%	100%				
Bank Condition	100%	100%				
Rock/Log Drops	100%	100%				
Vanes / J Hooks etc.	100%	100%				
Wads and Boulders	100%	100%				
Puzzle Creek Reach 1 (634 LF)						
Feature	**Initial**	**MY-01**	**MY-02**	**MY-03**	**MY-04**	**MY-05**
Riffles	100%	100%				
Pools	100%	100%				
Thalweg	100%	100%				
Meanders	100%	100%				
Bed General	100%	100%				
Bank Condition	100%	100%				
Rock/Log Drops	100%	100%				
Vanes / J Hooks etc.	100%	100%				
Wads and Boulders	100%	100%				
UT1 (3,339 LF)						
Feature	**Initial**	**MY-01**	**MY-02**	**MY-03**	**MY-04**	**MY-05**
Riffles	100%	100%				
Pools	100%	100%				
Thalweg	100%	100%				
Meanders	100%	100%				
Bed General	100%	100%				
Bank Condition	100%	100%				
Rock/Log Drops	100%	100%				
Vanes / J Hooks etc.	100%	100%				
Wads and Boulders	100%	100%				

Table 12. Visual Morphological Stability Assessment

Puzzle Creek Mitigation Project: Project No. 92522

Feature Category	Metric (per As-Built and reference baselines)	(# Stable) Number Performing as Intended	Total number per As-Built	Total Number / feet in unstable state	% Performing in Stable Condition	Feature Perfomance Mean or Total
Puzzle Creek Reach 1 (1,000 LF)						
A. Riffles	1. Present?	9	9	N/A	100	
	2. Armor stable (e.g. no displacement)?	9	9	N/A	100	
	3. Facet grades appears stable?	9	9	N/A	100	
	4. Minimal evidence of embedding/fining?	9	9	N/A	100	
	5. Length appropriate?	9	9	N/A	100	**100%**
B. Pools	1. Present? (e.g. not subject to severe aggradation or migration?)	10	10	N/A	100	
	2. Sufficiently deep (Max Pool D:Mean Bkf >1.6?)	10	10	N/A	100	
	3. Length appropriate?	10	10	N/A	100	**100%**
C. Thalweg[1]	1. Upstream of pool (structure) centering?	1	1	N/A	100	
	2. Downstream of pool (structure) centering?	1	1	N/A	100	**100%** [2]
D. Meanders	1. Outer bend in state of limited/controlled erosion?	6	6	N/A	N/A	
	2. Of those eroding, # w/concomitant point bar formation?	6	6	N/A	N/A	
	3. Apparent Rc within spec?	6	6	N/A	N/A	
	4. Sufficient floodplain access and relief?	6	6	N/A	N/A	**N/A**
E. Bed General	1. General channel bed aggradation areas (bar formation)	N/A	N/A	0/0	100	
	2. Channel bed degradation - areas of increasing down-cutting or head cutting?	N/A	N/A	0/0	100	**100%**
F. Vanes, Rock/Log Drop Structures	1. Free of back or arm scour?	1	1	N/A	100	
	2. Height appropriate?	1	1	N/A	100	
	3. Angle and geometry appear appropriate?	1	1	N/A	100	
	4. Free of piping or other structural failures?	1	1	N/A	100	**100%**
G. Wads/ Boulders, Coverlogs	1. Free of scour?	5	5	N/A	N/A	
	2. Footing stable?	5	5	N/A	N/A	**100%**
Puzzle Creek Reach 2 (634 LF)						
Feature Category	Metric (per As-Built and reference baselines)	(# Stable) Number Performing as Intended	Total number per As-Built	Total Number / feet in unstable state	% Performing in Stable Condition	Feature Perfomance Mean or Total
A. Riffles	1. Present?	5	5	N/A	100	
	2. Armor stable (e.g. no displacement)?	5	5	N/A	100	
	3. Facet grades appears stable?	5	5	N/A	100	
	4. Minimal evidence of embedding/fining?	5	5	N/A	100	
	5. Length appropriate?	5	5	N/A	100	**100%**
B. Pools	1. Present? (e.g. not subject to severe aggradation or migration?)	6	6	N/A	100	
	2. Sufficiently deep (Max Pool D:Mean Bkf >1.6?)	6	6	N/A	100	
	3. Length appropriate?	6	6	N/A	100	**100%**
C. Thalweg[1]	1. Upstream of pool (structure) centering?	1	1	N/A	100	
	2. Downstream of pool (structure) centering?	1	1	N/A	100	**100%** [2]
D. Meanders	1. Outer bend in state of limited/controlled erosion?	4	4	N/A	N/A	
	2. Of those eroding, # w/concomitant point bar formation?	4	4	N/A	N/A	
	3. Apparent Rc within spec?	4	4	N/A	N/A	
	4. Sufficient floodplain access and relief?	4	4	N/A	N/A	**N/A**
E. Bed General	1. General channel bed aggradation areas (bar formation)	N/A	N/A	0/0	100	
	2. Channel bed degradation - areas of increasing down-cutting or head cutting?	N/A	N/A	0/0	100	**100%**
F. Vanes, Rock/Log Drop Structures	1. Free of back or arm scour?	1	1	N/A	100	
	2. Height appropriate?	1	1	N/A	100	
	3. Angle and geometry appear appropriate?	1	1	N/A	100	
	4. Free of piping or other structural failures?	1	1	N/A	100	**100%**
G. Wads/ Boulders, Coverlogs	1. Free of scour?	2	2	N/A	N/A	
	2. Footing stable?	2	2	N/A	N/A	**100%**

UT1 (3,339 LF)						
Feature Category	Metric (per As-Built and reference baselines)	(# Stable) Number Performing as Intended	Total number per As-Built	Total Number / feet in unstable state	% Performing in Stable Condition	Feature Perfomance Mean or Total
A. Riffles	1. Present?	26	26	N/A	100	
	2. Armor stable (e.g. no displacement)?	26	26	N/A	100	
	3. Facet grades appears stable?	26	26	N/A	100	
	4. Minimal evidence of embedding/fining?	26	26	N/A	100	
	5. Length appropriate?	26	26	N/A	100	**100%**
B. Pools	1. Present? (e.g. not subject to severe aggradation or migration?)	24	24	N/A	100	
	2. Sufficiently deep (Max Pool D:Mean Bkf >1.6?)	24	24	N/A	100	
	3. Length appropriate?	24	24	N/A	100	**100%**
C. Thalweg[1]	1. Upstream of pool (structure) centering?	1	1	N/A	100	
	2. Downstream of pool (structure) centering?	1	1	N/A	100	**100%** [2]
D. Meanders	1. Outer bend in state of limited/controlled erosion?	21	21	N/A	N/A	
	2. Of those eroding, # w/concomitant point bar formation?	21	21	N/A	N/A	
	3. Apparent Rc within spec?	21	21	N/A	N/A	
	4. Sufficient floodplain access and relief?	21	21	N/A	N/A	**N/A**
E. Bed General	1. General channel bed aggradation areas (bar formation)	N/A	N/A	0/0	100	
	2. Channel bed degradation - areas of increasing down-cutting or head cutting?	N/A	N/A	0/0	100	**100%**
F. Vanes, Rock/Log Drop Structures	1. Free of back or arm scour?	1	1	N/A	100	
	2. Height appropriate?	1	1	N/A	100	
	3. Angle and geometry appear appropriate?	1	1	N/A	100	
	4. Free of piping or other structural failures?	1	1	N/A	100	**100%**
G. Wads/ Boulders, Coverlogs	1. Free of scour?	13	13	N/A	N/A	
	2. Footing stable?	13	13	N/A	N/A	**N/A**

[1] Thalweg feature is scored according to the centering of the thalweg over inverts of drop structures above pools and through the constructed riffle below pools since this reach is a step-pool channel without meander bends.

[2] Of the structures and riffles that contained flow, 100% had a centered thalweg. Centering of the thalweg for all remaining structures and riffles lacking baseflow that are located within the 'dry' portion of the reach will be re-assessed in the Year 2 monitoring report.

Table 13. Stream Reach Morphology and Hydraulic Data

Puzzle Creek Restoration Project #92522

Baseline Stream Summary
Puzzle Creek: Reach 1

Parameter	Regional Curve Equation	Reference Reach(es) Data			Design			(As-Built)			Yr 1			Yr 2			Yr 3			Yr 4			Yr 5		
Dimension - Riffle	Eq.	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Bankfull Width (ft)	17.9	7.8	11.3	14.8	-----	22.0	-----	19.8	18.4	21.3	17.7	18.0	18.4												
Floodprone Width (ft)	-----	17	39	62	-----	100+	-----	69	74	80	66	73	80												
Bankfull Mean Depth (ft)	2.03	0.80	1.45	2.10	-----	1.90	-----	2.10	2.30	2.49	2.21	2.34	2.46												
Bankfull Max Depth (ft)	-----	1.30	1.95	2.60	-----	2.5	-----	3.28	3.38	3.47	3.12	3.18	3.24												
Bankfull Cross Sectional Area (ft2)	40.8	7.5	19.3	31.0	-----	42.5	-----	44.7	45.2	45.7	40.8	42.1	43.4												
Width/Depth Ratio	-----	5.4	8.3	11.1	-----	11.6	-----	7.4	8.8	10.1	7.2	7.8	8.3												
Entrenchment Ratio	-----	1.8	4.9	7.9	-----	>4.5	-----	3.7	3.8	3.8	3.7	4.0	4.4												
Bank Height Ratio	-----	1.3	1.4	1.4	-----	1.3	-----	1.0	1.0	1.0	1.0	1.0	1.0												
Bankfull Velocity (fps)	-----	3.1	9.9	3.3	-----	4.5	-----	----	4.2	----	----	4.5	----												
Pattern																									
Channel Beltwidth (ft)	-----	-----	62	-----	68	-----	156	75	92	117	75	92	117												
Radius of Curvature (ft)	-----	-----	13	-----	35	-----	68	20	39	81	20	39	81												
Meander Wavelength (ft)	-----	-----	64	-----	136	-----	160	137	155	173	137	155	173												
Meander Width Ratio	-----	6.0	7.0	8.0	3.1	-----	7.1	----	5.0	----	----	5.1	----												
Profile																									
Riffle Length (ft)	-----	-----	-----	-----	25	-----	100	31	60	113	24	65	115												
Riffle Slope (ft/ft)	-----	0.001	0.029	0.058	-----	0.014	-----	0.005	0.012	0.019	0.003	0.013	0.028												
Pool Length (ft)	-----	-----	-----	-----	7	-----	60	34	57	86	14	35	63												
Pool Spacing (ft)	-----	24	33	42	58	-----	136	55	115	168	52	109	147												
Substrate and Transport Parameters																									
d16 / d35 / d50 / d84 / d95	-----	.5/.35/.92/30.04/56.91				----			----			-----			-----			-----			-----			-----	
Reach Shear Stress (competency) lb/f2	-----	-----	-----	-----	-----	0.90	-----	-----	0.90	-----	-----	0.96	-----												
Stream Power (transport capacity) W/m2	-----	-----	-----	-----	-----	4.0	-----	-----	3.8	-----	-----	4.3	-----												
Additional Reach Parameters																									
Channel length (ft)	-----	-----	-----	-----	-----	1000	-----	-----	1000	-----	-----	1000	-----												
Drainage Area (SM)	-----	0.2	1.9	2.3	-----	2.6	-----	-----	2.6	-----	-----	2.6	-----												
Rosgen Classification	-----	-----	C/E4	-----	-----	C4-5	-----	-----	E4	-----	-----	E4	-----												
Bankfull Discharge (cfs)	176.56	-----	190	-----	-----	190	-----	-----	190	-----	-----	190	-----												
Sinuosity	-----	-----	1.9	-----	-----	1.3	-----	-----	1.3	-----	-----	1.4	-----												
BF slope (ft/ft)	-----	-----	0.009	-----	0.009	0.009	0.009	-----	0.009	-----	-----	0.009	-----												

Table 13. Stream Reach Morphology and Hydraulic Data

Puzzle Creek Restoration Project #92522

Baseline Stream Summary
Puzzle Creek: Reach 2

Parameter	Regional Curve Equation	Reference Reach(es) Data			Design			(As-Built)			Yr 1			Yr 2			Yr 3			Yr 4			Yr 5		
Dimension - Riffle	Eq.	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Bankfull Width (ft)	24.7	7.8	11.3	14.8	-----	25.0	-----	----	25.6	----	----	26.6	----												
Floodprone Width (ft)	-----	17	39	62	-----	100+	-----	----	82	----	----	84	----												
Bankfull Mean Depth (ft)	2.58	0.80	1.45	2.10	-----	2.10	-----	----	2.48	----	----	2.48	----												
Bankfull Max Depth (ft)	-----	1.30	1.95	2.60	-----	2.70	-----	----	3.66	----	----	3.66	----												
Bankfull Cross Sectional Area (ft2)	68.0	7.5	19.3	31.0	-----	52.6	-----	----	63.4	----	----	66.1	----												
Width/Depth Ratio	-----	5.4	8.3	11.1	-----	11.9	-----	----	10.4	----	----	10.7	----												
Entrenchment Ratio	-----	1.8	4.9	7.9	-----	>4.0	-----	----	3.2	----	----	3.2	----												
Bank Height Ratio	-----	1.3	1.4	1.4	1.0	-----	1.2	----	1.0	----	----	1.0	----												
Bankfull Velocity (fps)	-----	3.1	9.9	3.3	-----	4.8	-----	----	3.9	----	----	3.8	----												
Pattern																									
Channel Beltwidth (ft)	-----	-----	62	-----	87	-----	198	62	113	154	62	113	154												
Radius of Curvature (ft)	-----	-----	13	-----	45	-----	62	37	46	53	37	46	53												
Meander Wavelength (ft)	-----	-----	64	-----	174	-----	248	234	256	269	234	256	269												
Meander Width Ratio	-----	6.0	7.0	8.0	3.5	-----	8.0	----	4.4	----	----	4.3	----												
Profile																									
Riffle Length (ft)	-----	-----	-----	-----	25	-----	100	32	56	87	42	64	98												
Riffle Slope (ft/ft)	-----	0.001	0.029	0.058	-----	0.016	-----	0.005	0.011	0.019	0.005	0.008	0.012												
Pool Length (ft)	-----	-----	-----	-----	7	-----	60	34	53	83	53	65	77												
Pool Spacing (ft)	-----	24	33	42	74	-----	174	85	121	168	79	121	182												
Substrate and Transport Parameters																									
d16 / d35 / d50 / d84 / d95	-----	.5/.35/.92/30.04/56.91				-----			-----			-----			-----			-----			-----			-----	
Reach Shear Stress (competency) lb/f2	-----	-----	-----	-----	-----	1.1	-----	-----	1.1	-----	-----	1.2	-----												
Stream Power (transport capacity) W/m2	-----	-----	-----	-----	-----	5.1	-----	-----	4.2	-----	-----	4.4	-----												
Additional Reach Parameters																									
Channel length (ft)	-----	-----	-----	-----	-----	634	-----	-----	634	-----	-----	634	-----												
Drainage Area (SM)	-----	0.2	1.9	2.3	-----	4.2	-----	-----	4.2	-----	-----	4.2	-----												
Rosgen Classification	-----	-----	C/E4	-----	-----	C4-5	-----	-----	E/C4	-----	-----	E/C4	-----												
Bankfull Discharge (cfs)	250	-----	190	-----	----	250	----	-----	250	-----	-----	250	-----												
Sinuosity	-----	-----	1.9	-----	-----	1.2	-----	-----	1.2	-----	-----	1.2	-----												
BF slope (ft/ft)	-----	-----	0.009	-----	-----	0.008	-----	-----	0.008	-----	-----	0.011	-----												

Table 13. Stream Reach Morphology and Hydraulic Data
Puzzle Creek Restoration Project #92522

Baseline Stream Summary: UT1

Parameter	Regional Curve Equation	Reference Reach(es) Data			Design			As-Built			Yr 1			Yr 2			Yr 3			Yr 4			Yr 5		
Dimension - Riffle	Eq.	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Bankfull Width (ft)	14.6	7.8	11.3	14.8	14.0	----	18.0	12.4	17.8	20.4	12.5	16.9	20.2												
Floodprone Width (ft)	-----	16.7	39.1	61.5	----	50+	----	44.1	58.1	76.1	41.4	57.3	76.3												
Bankfull Mean Depth (ft)	1.74	0.80	1.45	2.10	1.50	----	1.70	1.53	1.69	1.99	1.54	1.67	1.85												
Bankfull Max Depth (ft)	-----	1.3	2.0	2.6	-----	----	-----	2.3	2.73	3.5	2.4	2.64	3.3												
Bankfull Cross Sectional Area (ft2)	29.5	7.5	19.3	31.0	24.0	----	28.0	24.6	29.5	31.9	23.1	28.0	33.8												
Width/Depth Ratio	-----	5.4	8.3	11.1	8.2	----	12.0	6.2	10.9	13.1	6.7	10.3	13.0												
Entrenchment Ratio	-----	1.8	4.9	7.9	-----	----	-----	2.3	3.4	4.8	2.7	3.5	4.7												
Bank Height Ratio	-----	1.3	1.4	1.4	1.0	----	1.2	0.9	1.0	1.0	1.0	1.0	1.0												
Bankfull Velocity (fps)	-----	3.1	1.3	3.3	-----	5.4	-----	4.4	4.8	5.7	4.1	5.0	6.1												
Pattern																									
Channel Beltwidth (ft)	-----	-----	62	-----	50	----	93	44	66	87	44	66	87												
Radius of Curvature (ft)	-----	-----	13	-----	28	----	52	23	39	54	23	39	54												
Meander Wavelength (ft)	-----	-----	64	-----	130	----	213	143	175	220	143	175	220												
Meander Width Ratio	-----	6	7	8	3	----	7	4	4	4	4	4	4												
Profile																									
Riffle Length (ft)	-----	-----	-----	-----	22	----	100	25	46	55	23	51	85												
Riffle Slope (ft/ft)	-----	0.0006	0.0291	0.0576	0.0120	----	0.0200	0.0060	0.0122	0.0169	0.005	0.019	0.035												
Pool Length (ft)	-----	-----	-----	-----	25	----	50	17	33	52	13	22	38												
Pool Spacing (ft)	-----	24	33	42	50	----	90	56	91	127	55	92	131												
Substrate and Transport Parameters																									
d16 / d35 / d50 / d84 / d95	-----	.5/.4/.9/30/57			na/.4/1/30/57			.6/11/21/74/114			.3/6/14/60/98														
Reach Shear Stress (competency) lb/f2	-----	-----	-----	-----	-----	1.24	-----	-----	1.14	-----	-----	0.69	-----												
Stream Power (transport capacity) W/m2	-----	-----	-----	-----	-----	6.66	-----	-----	5.40	-----	-----	3.45	-----												
Additional Reach Parameters																									
Channel length (ft)	2975	-----	-----	-----	-----	3,246	-----	-----	3,339	-----		3,339													
Drainage Area (SM)	-----	0.20	1.25	2.30	-----	1.60	----	-----	1.60	-----	-----	1.60	-----												
Rosgen Classification	-----	-----	E5	-----	-----	C4-5	-----	-----	E/C4	-----	-----	E/C4	-----												
Bankfull Discharge (cfs)	-----	23	26	29	----	140	----	-----	140	-----	-----	140	-----												
Sinuosity	1.2	-----	1.9	----	-----	1.3	-----	-----	1.3	-----	-----	1.3	-----												
BF slope (ft/ft)	-----	-----	-----	-----	-----	0.016	-----	-----	0.016	-----	-----	0.009	-----												

Note: Although UT1 contains alternating restoration approaches, it was decided to leave UT1 as one reach for the purposes of this report as some of the reaches are less than 500 LF.

Table 14. Cross-section Morphology and Hydraulic Data
Puzzle Creek Restoration Project #92522

	Puzzle Creek Reach 1																	
Parameter	Cross Section 1 Riffle						Cross Section 2 Pool						Cross Section 3 Riffle					
	AB	MY1	MY2	MY3	MY4	MY5	AB	MY1	MY2	MY3	MY4	MY5	AB	MY1	MY2	MY3	MY4	MY5
Dimension																		
BF Width (ft)	21.3	18.4					23.3	24.1					18.4	17.7				
Floodprone Width (ft)	80.1	80.1					94.3	94.3					68.7	65.9				
BF Cross Sectional Area (ft2)	44.7	40.8					56.8	62.1					45.7	43.4				
BF Mean Depth (ft)	2.10	2.21					2.44	2.58					2.49	2.46				
BF Max Depth (ft)	3.28	3.12					4.75	4.90					3.47	3.24				
Width/Depth Ratio	10.1	8.3					9.5	9.4					7.4	7.2				
Entrenchment Ratio	3.8	4.4					4.1	3.9					3.7	3.7				
Wetted Perimeter (ft)	25.5	22.9					28.1	29.3					23.4	22.6				
Hydraulic Radius (ft)	1.8	1.8					2.0	2.1					2.0	1.9				
Substrate																		
d50 (mm)	-	-					-	-					-	-				
d84 (mm)	-	-					-	-					-	-				

	Puzzle Creek Reach 2											
Parameter	Cross Section 4 Riffle						Cross Section 5 Pool					
	AB	MY1	MY2	MY3	MY4	MY5	AB	MY1	MY2	MY3	MY4	MY5
Dimension												
BF Width (ft)	25.6	26.6					34.6	34.7				
Floodprone Width (ft)	82.2	83.8					59.5	64.1				
BF Cross Sectional Area (ft2)	63.4	66.1					99.9	105.8				
BF Mean Depth (ft)	2.48	2.49					2.89	3.05				
BF Max Depth (ft)	3.66	3.66					5.34	6.33				
Width/Depth Ratio	10.4	10.7					12.0	11.4				
Entrenchment Ratio	3.2	3.2					1.7	1.9				
Wetted Perimeter (ft)	30.6	31.5					40.3	40.8				
Hydraulic Radius (ft)	2.1	2.1					2.5	2.6				

Parameter	AB (2010)			MY-1 (2011)			MY-2 (2012)			MY-3 (2013)			MY-4 (2014)			MY-5 (2015)		
	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med
Pattern																		
Channel Beltwidth (ft)	62	154	103	62	154	103												
Radius of Curvature (ft)	20	81	42	20	81	42												
Meander Wavelength (ft)	137	269	206	137	269	206												
Meander Width Ratio	1.8	8.4	5.1	1.8	8.7	5.3												
Profile																		
Riffle length (ft)	31	113	60	24	115	64												
Riffle Slope (ft/ft)	0.005	0.019	0.013	0.003	0.028	0.010												
Pool Length (ft)	34	86	57	14	77	58												
Pool Spacing (ft)	55	168	115	52	182	115												
Substrate																		
d50 (mm)																		
d84 (mm)																		
Additional Reach Parameters																		
Valley Length (ft)	1,281			1,281														
Channel Length (ft)	1,634			1,634														
Sinuosity	1.3			1.4														
Water Surface Slope (ft/ft)	0.008			0.008														
BF Slope (ft/ft)	0.009			0.009														
Rosgen Classification	E/C4			E/C4														

UT1																								
Parameter	Cross Section 1 Riffle						Cross Section 2 Riffle						Cross Section 3 Pool						Cross Section 4 Riffle					
	AB	MY1	MY2	MY3	MY4	MY5	AB	MY1	MY2	MY3	MY4	MY5	AB	MY1	MY2	MY3	MY4	MY5	AB	MY1	MY2	MY3	MY4	MY5
Dimension																								
BF Width (ft)	12.4	12.5					19.0	20.2					24.8	27.4					20.4	20.1				
Floodprone Width (ft)	59.1	58.2					76.1	76.3					72.1	73.7					53.3	53.2				
BF Cross Sectional Area (ft2)	24.6	23.1					31.9	33.8					32.9	36.4					31.7	30.8				
BF Mean Depth (ft)	1.99	1.85					1.68	1.67					1.33	1.33					1.55	1.54				
BF Max Depth (ft)	2.62	2.48					2.33	2.42					2.47	2.87					2.42	2.40				
Width/Depth Ratio	6.2	6.7					11.3	12.1					18.7	20.6					13.1	13.0				
Entrenchment Ratio	4.8	4.7					4.0	3.8					2.9	2.7					2.6	2.7				
Wetted Perimeter (ft)	16.4	16.2					22.4	23.6					27.5	30.0					23.5	23.1				
Hydraulic Radius (ft)	1.5	1.4					1.4	1.4					1.2	1.2					1.3	1.3				
Substrate																								
d50 (mm)	----	----					----	----					----	----					----	----				
d84 (mm)	----	----					----	----					----	----					----	----				

Parameter	Cross Section 5 Pool						Cross Section 6 Riffle					
	AB	MY1	MY2	MY3	MY4	MY5	AB	MY1	MY2	MY3	MY4	MY5
Dimension												
BF Width (ft)	25.5	27.6					19.6	14.9				
Floodprone Width (ft)	66.3	66.2					44.1	41.4				
BF Cross Sectional Area (ft2)	53.2	52.3					30.0	24.2				
BF Mean Depth (ft)	2.09	1.90					1.53	1.62				
BF Max Depth (ft)	5.39	5.38					3.53	3.26				
Width/Depth Ratio	12.2	14.6					12.8	9.2				
Entrenchment Ratio	2.6	2.4					2.3	2.8				
Wetted Perimeter (ft)	29.6	31.4					22.6	18.1				
Hydraulic Radius (ft)	1.8	1.7					1.3	1.3				
Substrate												
d50 (mm)	----	----					----	----				
d84 (mm)	----	----					----	----				

Parameter	AB (2010)			MY-1 (2011)			MY-2 (2012)			MY-3 (2013)			MY-4 (2014)			MY-5 (2015)		
	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med
Pattern																		
Channel Beltwidth (ft)	44	87	66	44	87	66												
Radius of Curvature (ft)	23	54	39	23	54	39												
Meander Wavelength (ft)	143	220	175	143	220	175												
Meander Width Ratio	1.7	7.0	4.4	1.6	7.0	4.3												
Profile																		
Riffle length (ft)	25	55	52	23	85	58												
Riffle Slope (ft/ft)	0.006	0.017	0.011	0.005	0.035	0.016												
Pool Length (ft)	17	52	30	13	38	22												
Pool Spacing (ft)	56	127	95	55	131	89												
Substrate																		
d50 (mm)		21			14													
d84 (mm)		74			60													
Additional Reach Parameters																		
Valley Length (ft)		2,915			2,915													
Channel Length (ft)		3,339			3,339													
Sinuosity		1.3			1.3													
Water Surface Slope (ft/ft)		0.014			0.01													
BF Slope (ft/ft)		0.016			0.01													
Rosgen Classification		E/C4			E/C4													

UT2																										
Parameter	Cross Section 1 Pool																									
	AB	MY1	MY2	MY3	MY4	MY5																				
Dimension																										
BF Width (ft)	10.1	10.7																								
Floodprone Width (ft)	29.4	29.4																								
BF Cross Sectional Area (ft2)	15	15.9																								
BF Mean Depth (ft)	1.48	1.48																								
BF Max Depth (ft)	2.89	2.72																								
Width/Depth Ratio	6.8	7.3																								
Entrenchment Ratio	2.9	2.7																								
Wetted Perimeter (ft)	13.1	13.7																								
Hydraulic Radius (ft)	1.1	1.2																								
Substrate																										
d50 (mm)	----	----	----																							
d84 (mm)	----	----	----																							

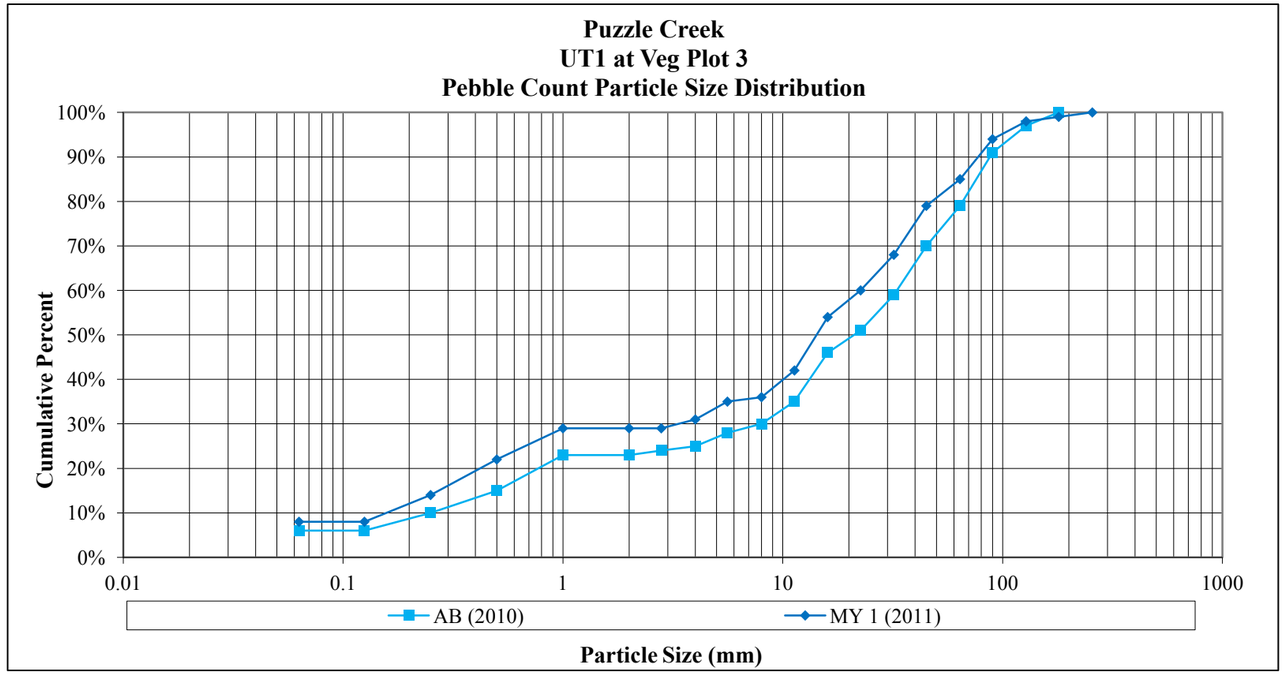
Parameter	AB (2010)			MY-1 (2011)			MY-2 (2012)			MY-3 (2013)			MY-4 (2014)			MY-5 (2015)		
	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med
Pattern																		
Channel Beltwidth (ft)		----			----													
Radius of Curvature (ft)		----			----													
Meander Wavelength (ft)		----			----													
Meander Width Ratio		----			----													
Profile																		
Riffle length (ft)		----			----													
Riffle Slope (ft/ft)		----			----													
Pool Length (ft)		----			----													
Pool Spacing (ft)		----			----													
Substrate																		
d50 (mm)																		
d84 (mm)																		
Additional Reach Parameters																		
Valley Length (ft)		41			41													
Channel Length (ft)		52			52													
Sinuosity		1.3			1.3													
Water Surface Slope (ft/ft)		0.016			0.019													
BF Slope (ft/ft)		0.016			0.012													
Rosgen Classification		E			E													

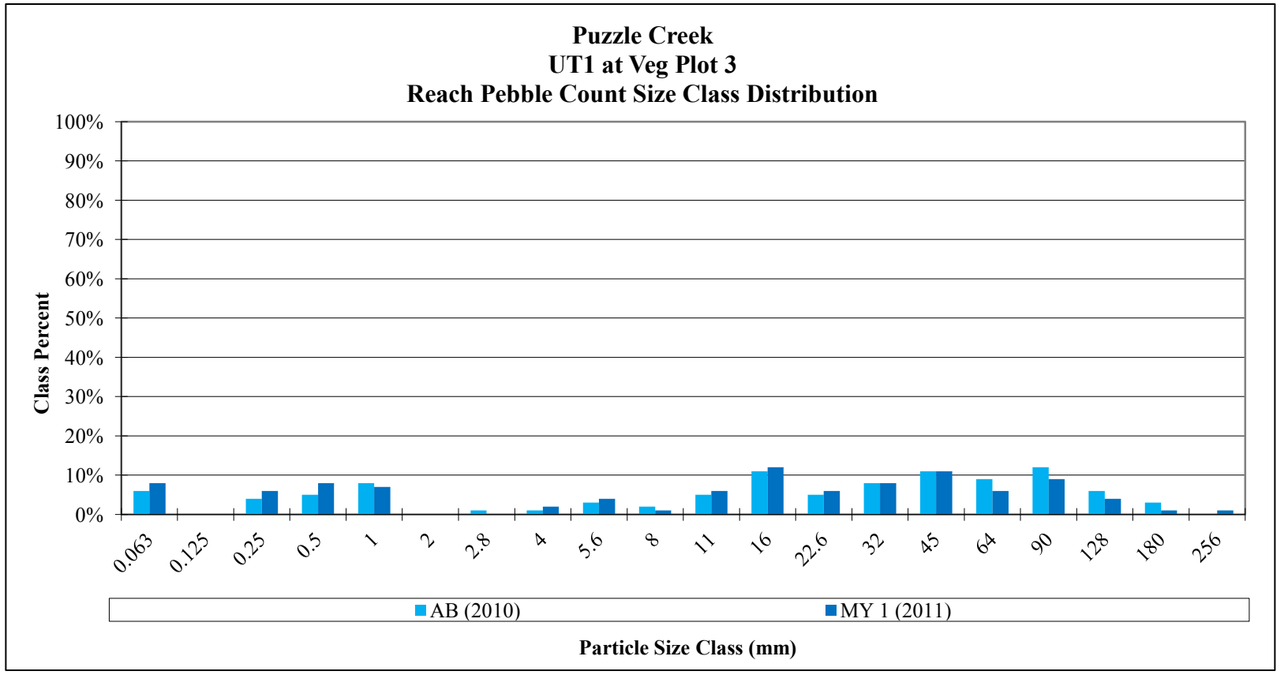
Cross-Section Pebble Count (UT1)
Puzzle Creek Mitigation Project, EEP# 92522

SITE OR PROJECT:	Puzzle Creek
REACH/LOCATION:	Riffle in front of Veg Plot 3
FEATURE:	Riffle

			2011		
MATERIAL	**PARTICLE**	**SIZE (mm)**	**Total**	**Class %**	**% Cum**
Silt/Clay	Silt / Clay	< .063	8	8%	8%
Sand	Very Fine	.063 - .125			8%
	Fine	.125 - .25	6	6%	14%
	Medium	.25 - .50	8	8%	22%
	Coarse	.50 - 1.0	7	7%	29%
	Very Coarse	1.0 - 2.0			29%
Gravel	Very Fine	2.0 - 2.8			29%
	Very Fine	2.8 - 4.0	2	2%	31%
	Fine	4.0 - 5.6	4	4%	35%
	Fine	5.6 - 8.0	1	1%	36%
	Medium	8.0 - 11.0	6	6%	42%
	Medium	11.0 - 16.0	12	12%	54%
	Coarse	16 - 22.6	6	6%	60%
	Coarse	22.6 - 32	8	8%	68%
	Very Coarse	32 - 45	11	11%	79%
	Very Coarse	45 - 64	6	6%	85%
Cobble	Small	64 - 90	9	9%	94%
	Small	90 - 128	4	4%	98%
	Large	128 - 180	1	1%	99%
	Large	180 - 256	1	1%	100%
Boulder	Small	256 - 362			100%
	Small	362 - 512			100%
	Medium	512 - 1024			100%
	Large-Very Large	1024 - 2048			100%
Bedrock	Bedrock	> 2048			100%
Total % of whole count			100	100%	100%

Summary Data	
Channel materials	
D_{50} =	14.00
D_{84} =	60.00
D_{95} =	98.00





Puzzle Creek Mitigation Project
Puzzle Creek Photo Log - Photo Points (January 2012)

Notes:

1. Photo point locations are shown on the plan views in the actual location the picture was taken.
2. All points are marked with a wooden stake and flagging tape.

Photo Point 1: facing downstream

Photo Point 2: facing upstream

Photo Point 2: facing downstream

Photo Point 3: facing upstream

Photo Point 3: facing downstream

Photo Point 4: facing upstream

Photo Point 4: facing downstream

Photo Point 5: facing upstream

Photo Point 5: facing downstream

Photo Point 6: facing upstream

Photo Point 6: facing downstream

Photo Point 7: facing upstream

Puzzle Creek Mitigation Project
UT1 Photo Log - Photo Points (January 2012)

Notes:

1. Photo point locations are shown on the plan views in the actual location the picture was taken.
2. All points are marked with a wooden stake and flagging.

Photo Point 1: facing downstream

Photo Point 1: facing upstream

Photo Point 2: facing downstream

Photo Point 2: facing upstream

Photo Point 3: facing downstream

Photo Point 3: facing upstream

Photo Point 4: facing downstream

Photo Point 4: facing upstream

Photo Point 5: facing downstream

Photo Point 5: facing upstream

Photo Point 6: facing downstream

Photo Point 6: facing upstream

Photo Point 7: facing downstream

Photo Point 7: facing upstream

Photo Point 8: facing upstream

Photo Point 9: facing downstream

Photo Point 9: facing upstream

Photo Point 10: facing downstream

Photo Point 10: facing upstream

Photo Point 11: facing downstream

Photo Point 11: facing upstream

Photo Point 12: facing downstream

Photo Point 12: facing upstream

Photo Point 13: facing downstream

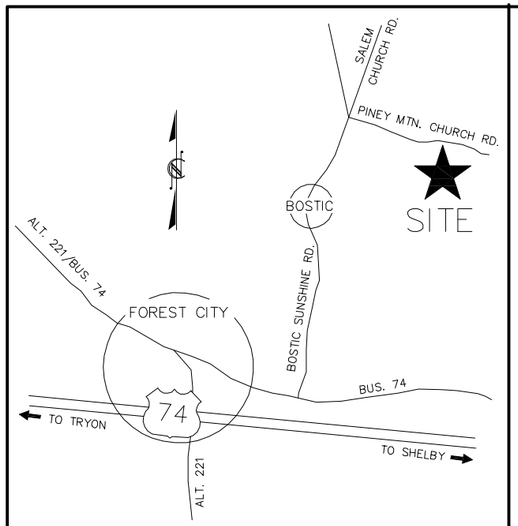
Photo Point 13: facing upstream

Photo Point 14: facing upstream

Photo Point 15: facing downstream

Photo Point 15: facing upstream

Photo Point 16: facing upstream



VICINITY MAP
NOT TO SCALE

NC Ecosystem Enhancement Program

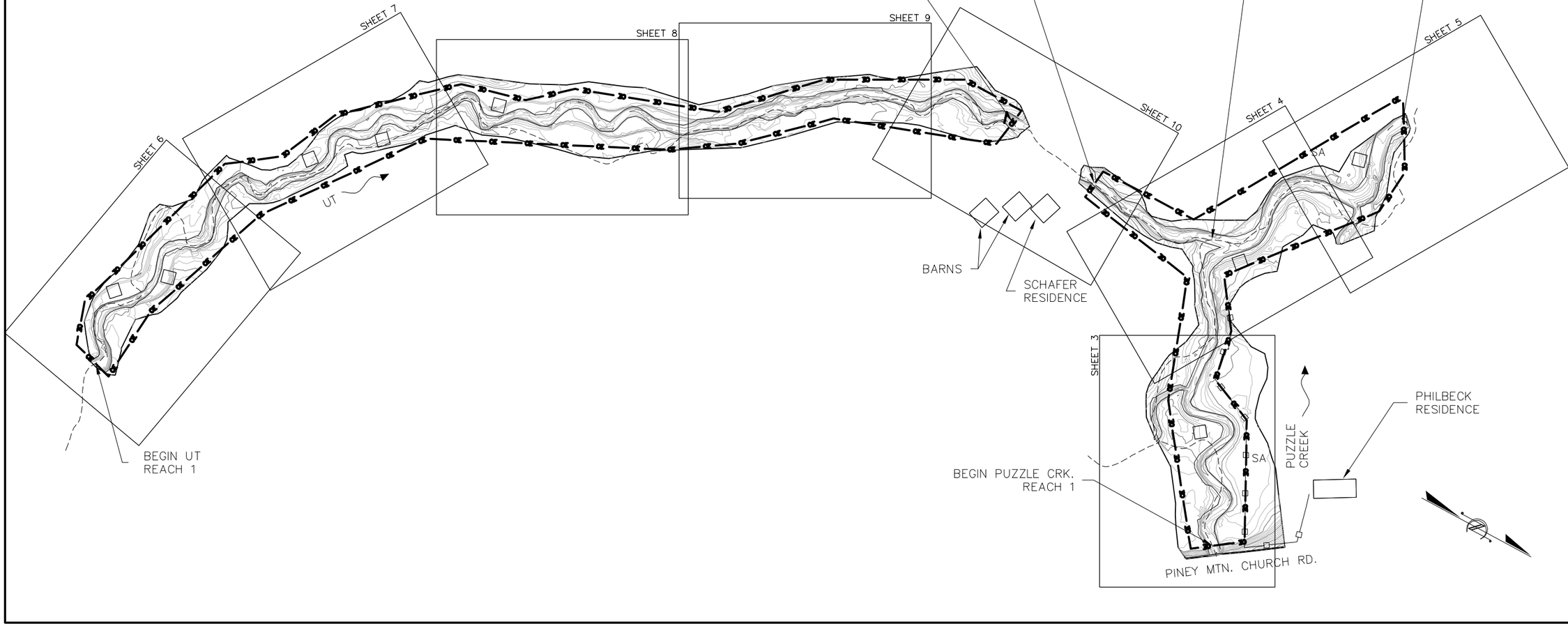
Puzzle Creek Restoration Project

Bostic, North Carolina

INDEX OF SHEETS

Datum Description:

Horizontal Datum is on NCGS NAD 83. Temporary contol points are present on site and will be used to establish grade and position by a Baker representative at the time of construction.



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DRAWN: MDR
APPROVED: MMC

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PUZZLE CREEK RESTORATION PROJECT
BOSTIC, NC
YEAR 1 MONITORING
TITLE SHEET

Prepared for:
Ecosystem Enhancement Program
2728 Capitol Blvd, Suite 1H 103
Raleigh, NC 27604
Phone: 919-715-0476
Fax: 919-715-2219

Baker Project Number
AH-109277

Date: 5/4/12

Drawing Sheet No.
Sheet 1 of 10

LEGEND OF SYMBOLS

TREE

PHOTO POINT

COVER LOG

ROOT WAD

ROCK VANE

LOG VANE

BOULDER TOE

GEO LIFT

FORD CROSSING

DESIGN THALWEG

TOP OF BANK

CHANNEL

EXISTING THALWEG

CE

CONSERVATION EASEMENT

FENCE

CONTOUR–INDEX

CONTOUR–INTERMEDIATE

DESIGNED: MMC
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APPROVED: MMC

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PUZZLE CREEK RESTORATION PROJECT
BOSTIC, NC
YEAR 1 MONITORING
LEGEND OF SYMBOLS

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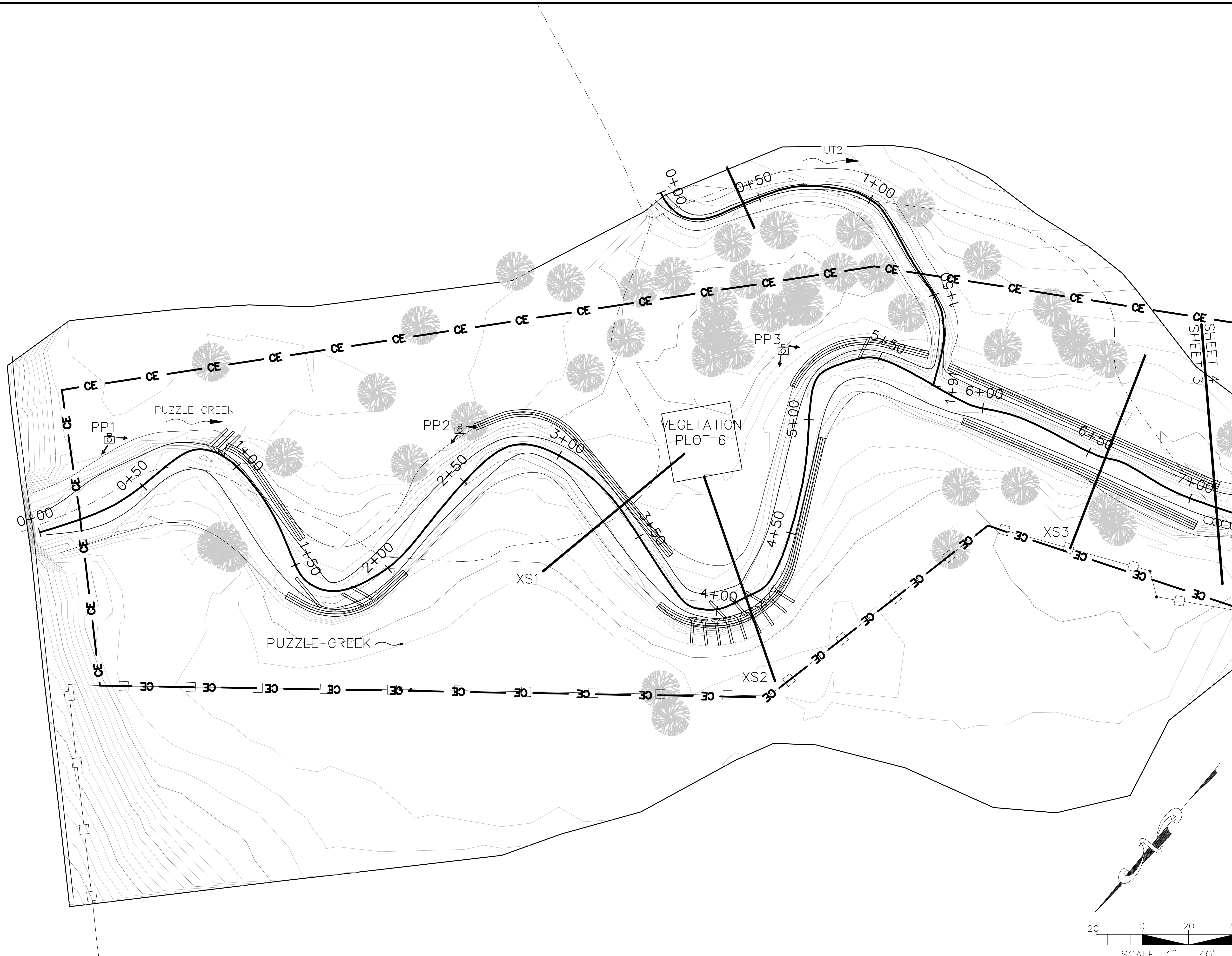
Baker Project Number
AH-109277

Date: 5/4/12

Drawing Sheet No.
Sheet 2 of 10



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PUZZLE CREEK RESTORATION PROJECT
BOSTIC, NC

YEAR 1 MONITORING PLAN

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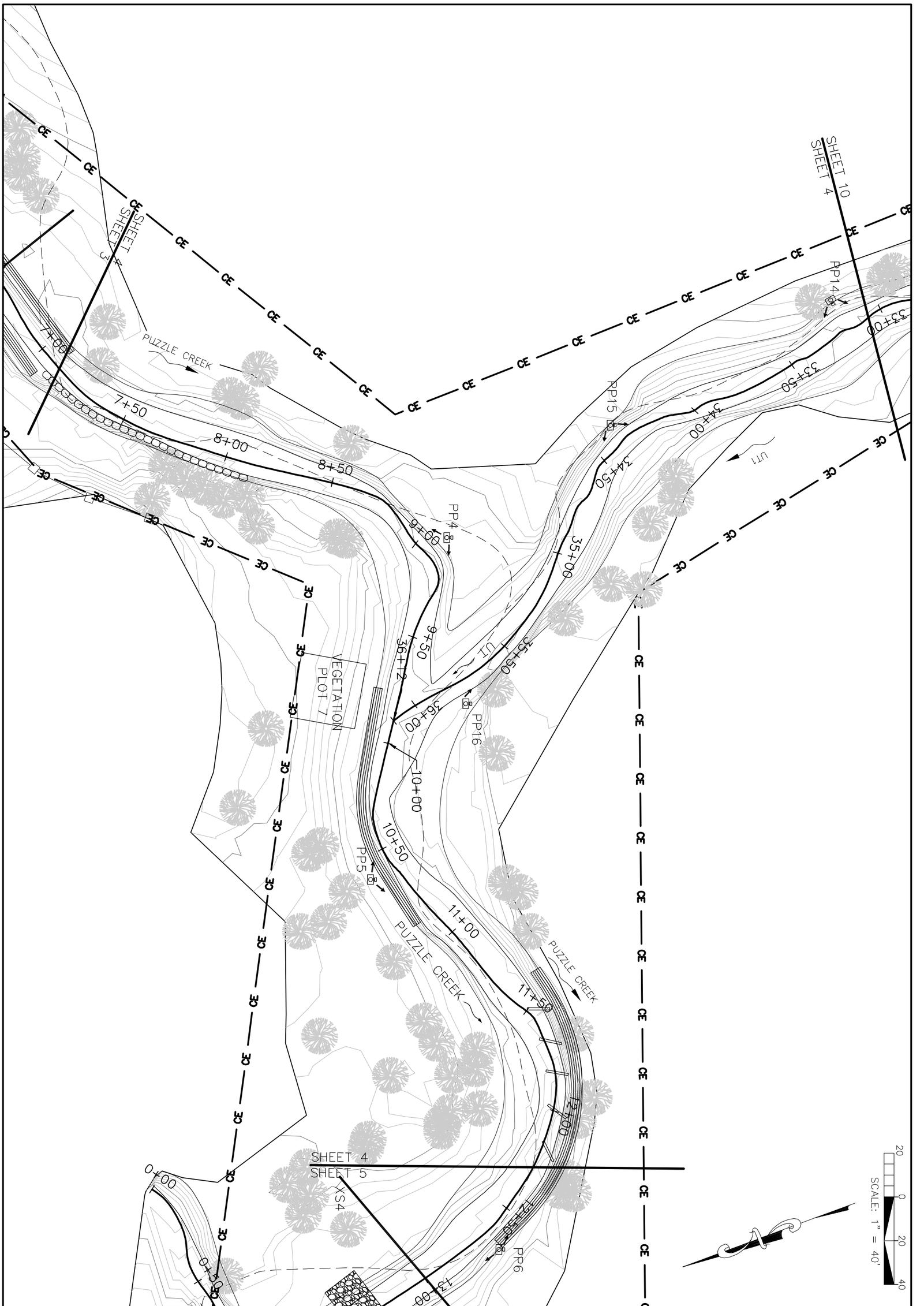
Baker Project Number
AH-109277

Date: 5/4/12

Drawing Sheet No.
Sheet 3 of 10



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PUZZLE CREEK RESTORATION PROJECT
BOSTIC, NC
YEAR 1 MONITORING PLAN

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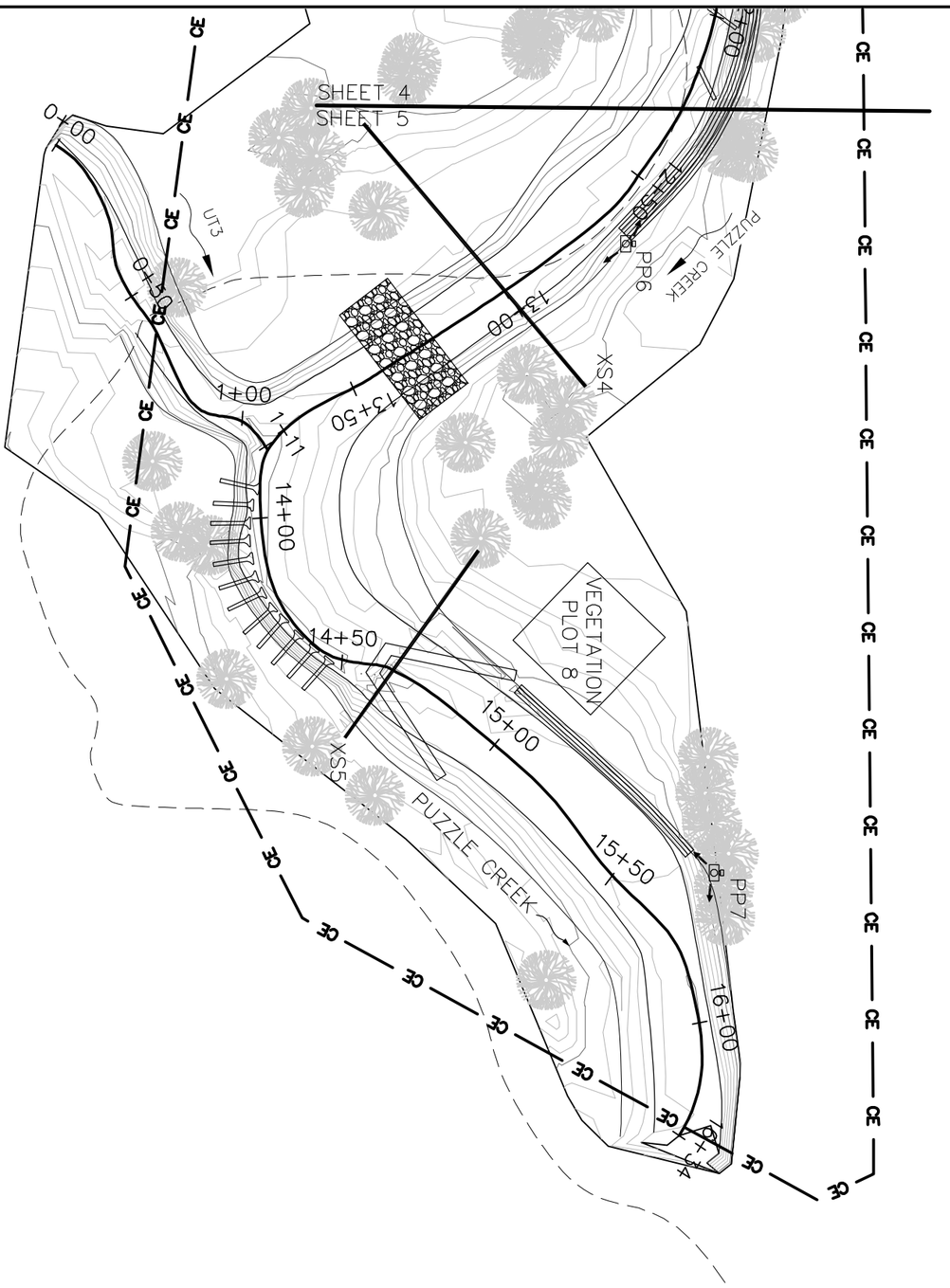
Baker Project Number: AH-109277
Date: 5/4/12
Drawing Sheet No.: Sheet 4 of 10



SCALE: 1" = 40'

20 0 20 40

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PUZZLE CREEK RESTORATION PROJECT
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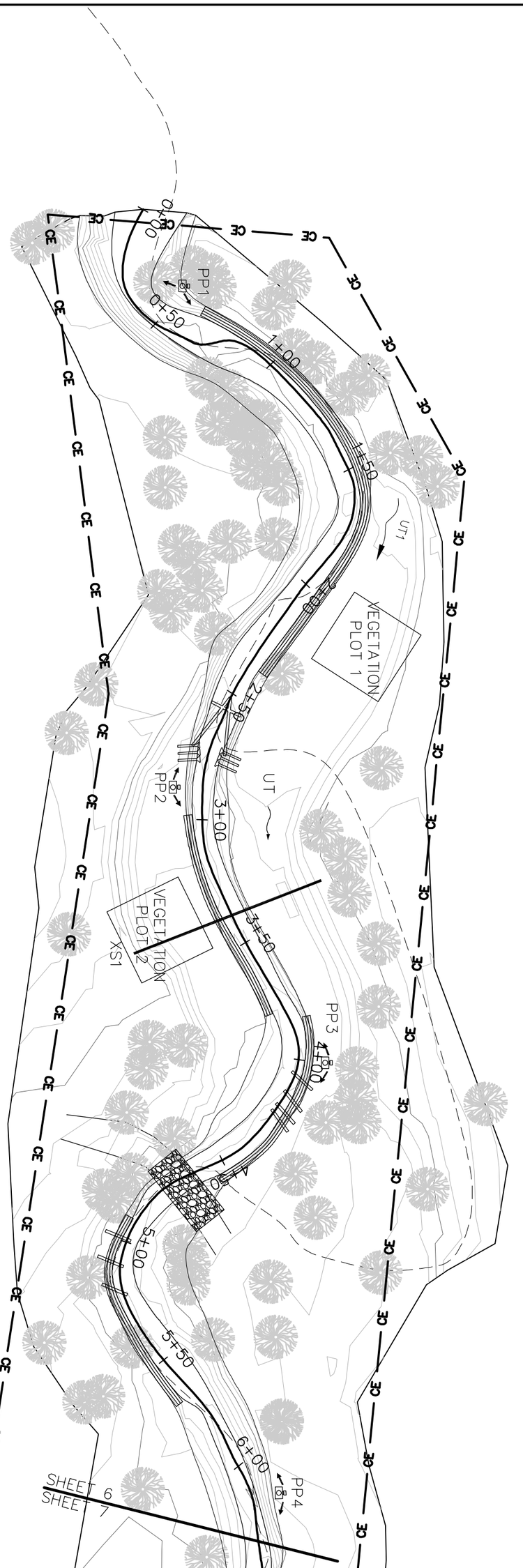
APPROVED: MMC

Baker Project Number: All-109277
Date: 5/4/12
Drawing Sheet No.
Sheet 5 of 10



SCALE: 1" = 40'

20 0 20 40

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BOSTIC, NC
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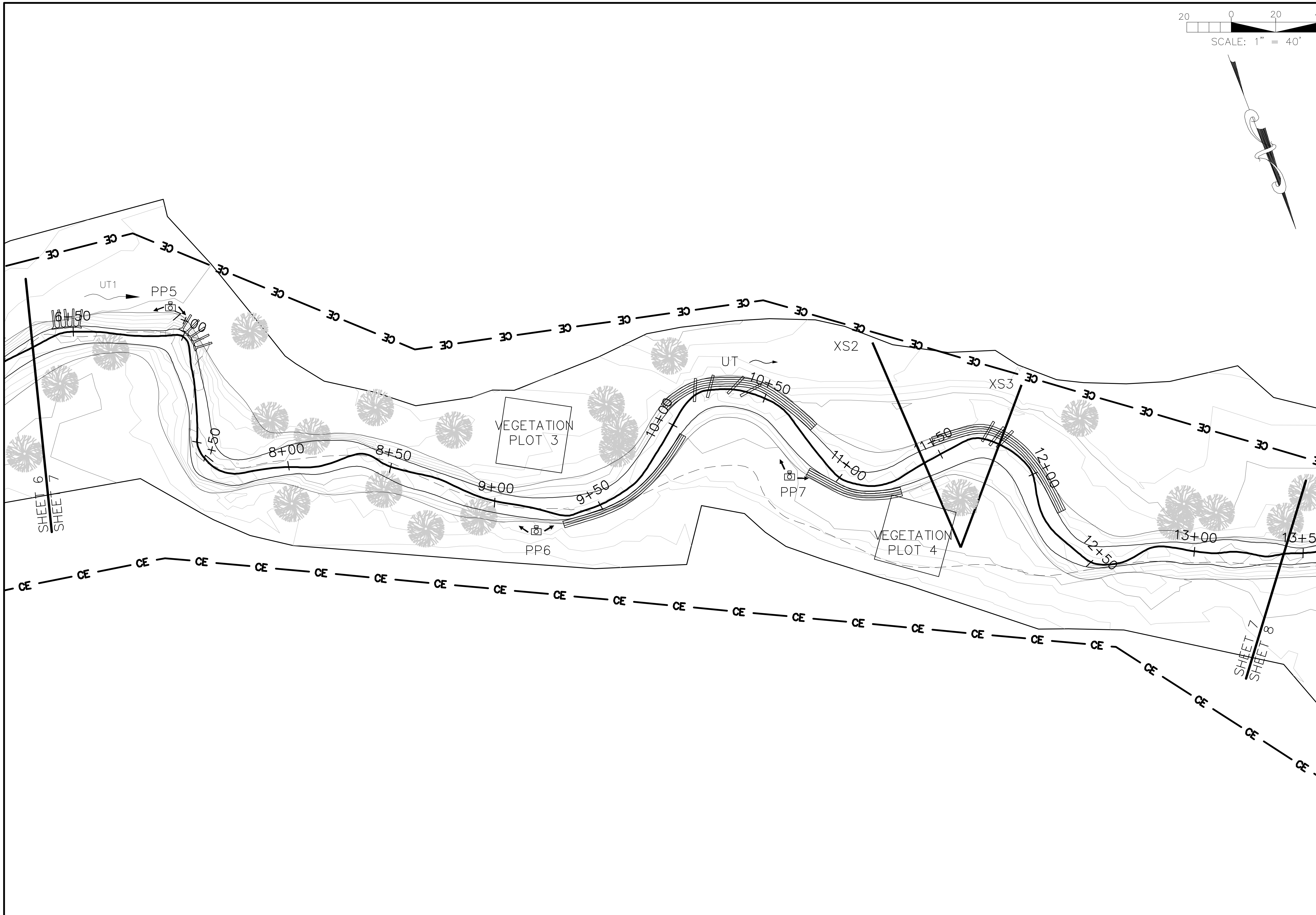
Baker Project Number: 124112
Date: 5/4/12
Drawing Sheet No.: 6 of 10
Sheet



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DRAWN:	MDR
APPROVED:	MMC

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BOSTIC, NC
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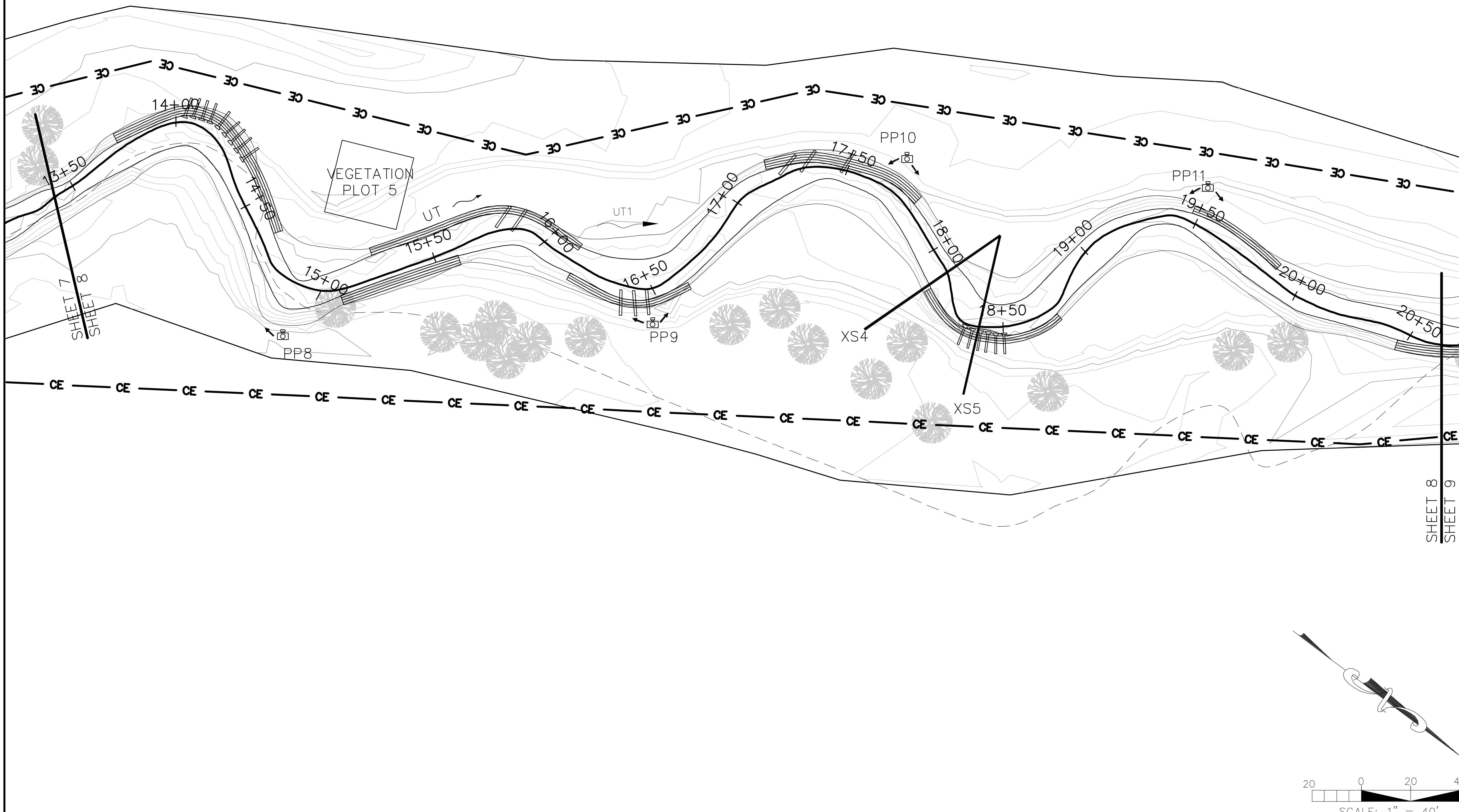
AH-109277
Date: 5/4/12
Drawing Sheet No.
Sheet 7 of 10



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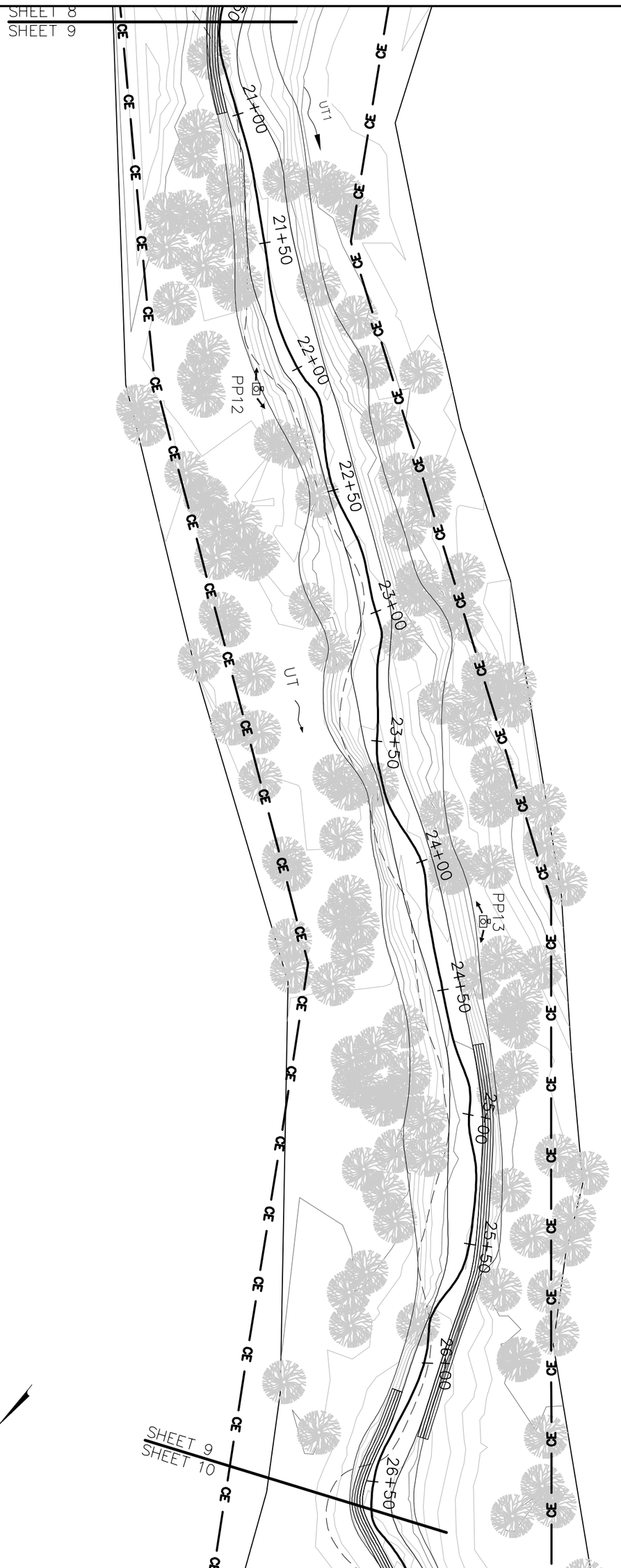

SCALE: 1" = 40'

20 0 20 40

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PUZZLE CREEK RESTORATION PROJECT
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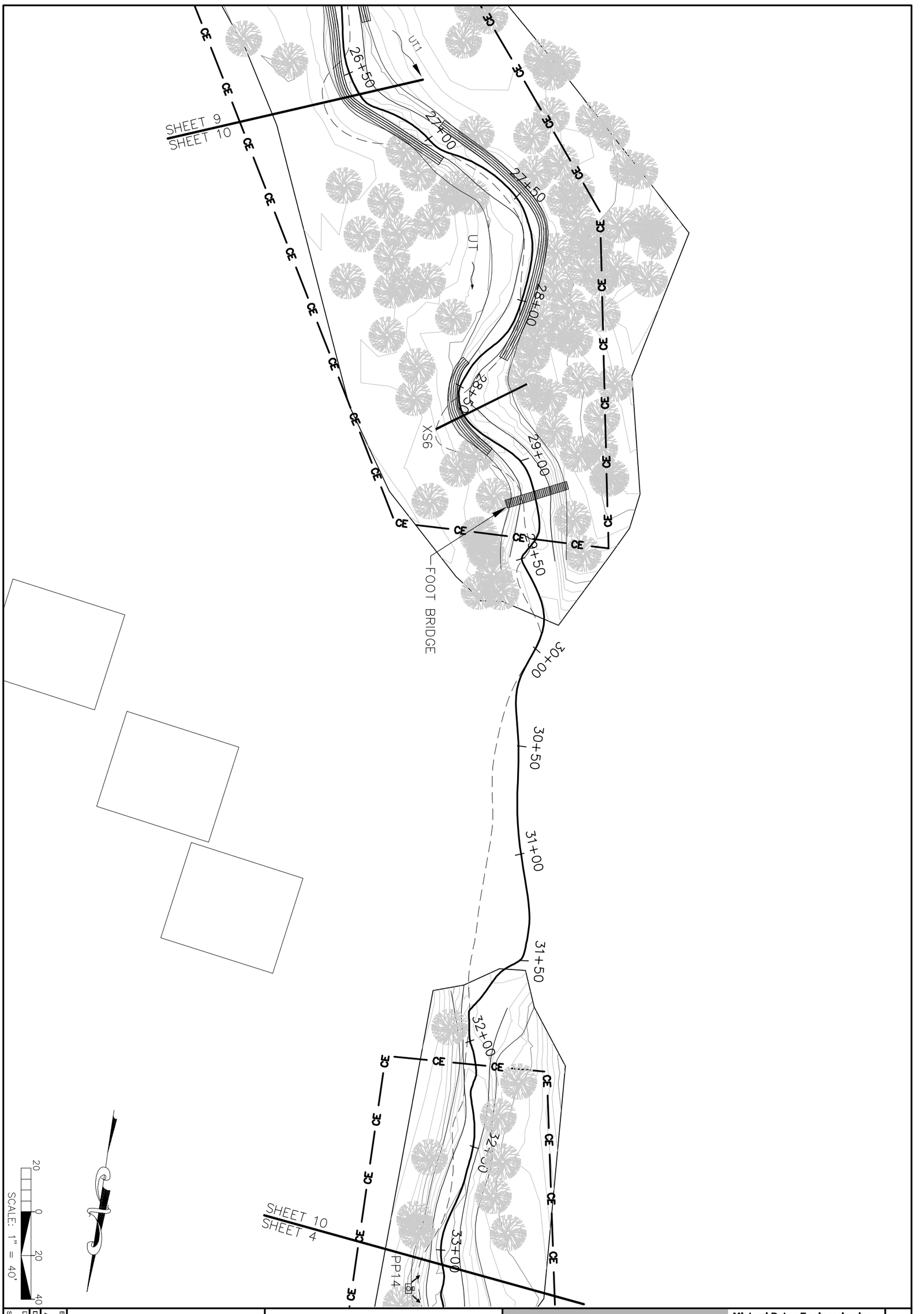
Drawing Sheet No.: Sheet 9 of 10



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Drawing Sheet No.: Sheet 10 of 10