RESTORATION DESIGN OF COLDWATER FORK FOLLOWING THE OCTOBER 11, 2000 SLURRY SPILL[1]

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Abstract. On Wednesday morning, October 11, 2000, a breach in the 72-acre Big Branch slurry impoundment caused the release of approximately 250 million gallons of coal slurry, a substance consisting of coal fines, other particles and water, into the Coldwater Fork and Wolf Creek Watersheds, through two mine portals ultimately affecting more than 100 miles of stream. Arguably, the most severely impacted section of stream was Coldwater Fork downstream of the portal. During the cleanups, approximately one mile of Coldwater Fork was relocated, resulting in an incised trapezoidal channel over much of the stream. While portions of the stream, particularly sections with good floodplain access, have recovered, other reaches are characterized by headcuts and a lack of riffle-pool sequences. Working for the Martin County Coal Corporation (MCCC), Fuller, Mossbarger, Scott and May, Inc. (FMSM) performed an assessment of the Upper Middle Fork of Coldwater Fork, and prepared a design and directed construction for nearly 6,000 feet of stream restoration.

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Introduction

An uncontrolled slurry release caused by the breaching of the Big Branch Slurry Impoundment on October 11, 2000, resulted in the release of approximately 250 million gallons of slurry into the Coldwater Fork watershed. While many miles of stream were affected in both watersheds, a mile-long section of Coldwater Fork immediately below the impoundment was the most severely impacted, with up to 6 feet of slurry spilling out into the floodplain. The emergency response to this spill required pumping of slurry out of the area as well as excavation with heavy equipment as shown in Fig. 1. Cleanup efforts were initiated immediately by Martin County Coal Corporation and were conducted around the clock to remove the slurry as quickly as possible. During the cleanup, the focus was on minimizing impacts to existing streams, however, the upper middle portion of Coldwater Fork was realigned as debris and slurry were removed from the Coldwater Fork valley resulting in a stream with a nearly trapezoidal cross section and boulder armoring.

Figure 1: Clean up Efforts along the Creek.

Since the slurry release occurred, significant segments of Coldwater Fork have exhibited a remarkable recovery. Portions of Coldwater Fork are re-establishing stable riffle-pool sequences and riffle armor is beginning to accumulate in the upstream portion of the stream. Fig. 2 shows a recovering segment of Coldwater Fork. The remaining

Figure 2: Natural Recovery of the Stream.

sections of Coldwater Fork lack appropriate riffle/pool sequences and/or exhibit head cuts or substantial bank erosion. Banks largely consist of clay and sand and the channel bottom is primarily comprised of sand and gravel. Both fish and macro-invertebrates are returning to the stream as well. At the down-stream limits of the project near the confluence of Walnut Fork, a series of head-cuts (Fig. 3) have formed threatening to destabilize the recovering portions of the creek if they continue to work upstream. In addition, a head-cut is also forming near the confluence with Lynn Bark Branch.

The stream restoration design for this project focused on minimizing reworking of the stream in areas exhibiting good natural recovery, and restoration of destabilized areas using natural channel design techniques to achieve proper dimension, pattern and profile, especially within areas exhibiting head-cuts. The new channel was designed using dimensionless ratios developed from a reference reach utilizing the RiverMORPH© Stream Restoration software.

Figure 3: View of Head-cut

Methodology

Channel dimensions developed from reference reach data were used to design areas where the channel alignment and geometry were altered during the slurry cleanup. A reference reach was used to develop dimensionless pattern, profile and cross section ratios relative to the bankfull widths. (Rosgen, 1998) The data collected provided estimates of bankfull width as a function of drainage area, pool-to-pool spacing, sinuosity, meander belt width, bed material load particle distributions, hydraulic slopes, width/depth ratios and entrenchment ratios.

The project was divided into five reaches based on drainage area and sub-catchment of similar bed material, bank composition and bankfull slope. Three reaches were on Coldwater Fork and two were on Lynn Bark and Walnut Fork, tributaries to Coldwater Fork. Lynn Bark and Walnut Fork were considerably steeper than Coldwater Fork following the emergency cleanup. Though all five reaches were excavated to bare soil during cleanup, coarse material appears to be migrating down the system and is accumulating in riffles.

The approach to determining bankfull properties for Coldwater Fork and its tributaries differed from the typical methodology. Following the emergency cleanup, re-alignment, and placement of boulders along the banks of Coldwater Fork and its tributaries, there was a relative absence of bankfull indicators due to bank armoring and recent excavation of the channel. Reliable bankfull indicators from Wolf Creek, a nearby stream also used as the reference reach, were used as support for the few bankfull indicators present along Coldwater Fork in the following fashion. First, the ratio of the bankfull cross sectional area for the Wolf Creek reach drainage area to the predicted bankfull cross sectional area shown on the Eastern United States regional curve reference (Rosgen, 1996) for the same drainage area was derived. Next, this ratio was applied to the predicted bankfull cross sectional areas on the Eastern United States Regional Curve for the drainage areas of the respective reaches of Coldwater Fork and its tributaries. The estimated bankfull cross sectional area was then compared to possible bankfull indicators observed during the geomorphic survey. Indicators corresponding to these predicted bankfull properties were used to determine bankfull elevation throughout the reach. Table 1 illustrates selected geomorphic data for each reach in the project.

Table 1. Summary of Channel Conditions – Impacted Reaches

	Coldwater Fork				
	Reach 1	**Reach 2**	**Reach 3**	**Lynn Bark**	**Walnut FK**
Flow Regime	Perennial	Perennial	Perennial	Perennial	Perennial
Stream Classification	B4c	C4	E4	B4c	C4
Drainage Area	2.85 mi^2	6.98 mi^2	8.97 mi^2	3.92 mi^2	1.99 mi^2
Bankfull Area	32 ft^2	62 ft^2	73 ft^2	39 ft^2	30 ft^2
Bankfull Width (W_{bkf})	23.1 ft	30.8 ft	26.5 ft	28 ft	22.7 ft
Bankfull Depth (D_{bkf})	1.4 ft	2.0 ft	2.7 ft	1.4 ft	1.3 ft
Valley Type	Type 7/8	Type 8	Type 8	Type 8	Type 8
Valley Slope	0.0097	0.0043	0.0029	0.011	0.026
Sinuosity	1.08	1.14	1.04	1.09	1.04
Bankfull Slope	0.009 ft/ft	0.0038 ft/ft	0.0028 ft/ft	0.0049 ft/ft	0.0037 ft/ft
Width/Depth Ratio	17	15	10	20	17
Entrenchment Ratio	1.44	3.18	2.48	2.09	5.25
Stream bank Erosion Potential	Moderate	Moderate to High	Moderate to High	Moderate to High	Moderate to High
Flood-Prone Width	33 ft	168 feet	66 feet	58 feet	119 feet

Stream Design.

Natural channel design techniques were utilized for the design of the improvements to Coldwater Fork and its tributaries. This methodology utilized a reference reach, a stream in stable plan, profile and dimension, preferably from the same hydro-physiographic providence but from the same valley type at a minimum, as a blueprint for design. The design consisted of a combination of stream relocation augmented with in-stream structures; bankfull bench construction augmented with in-stream structures; and placement of in-stream structures without significant alteration to the cross section. In the relocated sections, particular attention was given to improving the stream pattern and cross section based on the reference reach. Structures to maintain grade, concentrate flows away from the banks and improve habitat are included in the form of cross vanes and j-hooks/log vanes. Riffle armor was also included for the relocated sections. The relocation and stabilization design increases the length of Coldwater Fork from approximately 4,995 to 5,385 linear feet of stream by increasing the sinuosity in the relocated reaches. An additional 70 linear feet and 155 linear feet of stream will be added to Lynn Bark Fork and Walnut Fork, respectively. As a result of the increased channel length, the bankfull slope is decreased, which results in a decrease in shear stress.

Figure 4: View of Reference Reach

Where the bankfull bench construction is utilized, a fifteen to twenty foot flat area will be excavated on the left bank at bankfull. The bench is designed to reduce shear stresses during flows above bankfull. Cross vanes and j-hooks/log vanes will be used to provide grade control and bank protection, respectively.

In order to verify that the designed reach can efficiently transport sediment without excessive aggregation or degradation, entrainment calculations were performed to determine the sediment transport competency. The critical dimensionless shear stress was calculated utilizing Andrew's equations (Andrews and Erman, 1986; Andrews and Nankervis, 1995). These equations were modified by Rosgen (2002) whereby sediment data from bar samples are used instead of sub-pavement data:

$$\tau c_i = 0.0384 \left(\frac{d_{i-Bar}}{d_{50-Bed}} \right)^{-0.887} \tag{1}$$

where c_i = critical dimensionless shear stress
$d_{i\text{-}Bar}$ = largest particle in bar sample (mm)
$d_{50\text{-}Bed}$ = median particle size from riffle pebble count (mm)

The bankfull mean depth required to mobilize the largest particle encountered in a bar sample was determined using Equation 2:

$$d = \frac{(\tau c_i \times 1.65 \times d_i / 304.8)}{S} \tag{2}$$

where d = required mean depth (ft)
d_i = largest particle in bar sample (mm)
S = riffle slope at bankfull

Using Equations 1 and 2, the depth required for sediment transport competency was compared to the design depth. If they differed, the dimensions were changed in an iterative process until they were within approximately ten percent of each other. Table 2 summarizes other design parameters.

Table 2. Natural Channel Design Parameters

	Reach 1	Reach 2	Reach 3	Lynn Bark	Walnut FK
Designed Valley Slope	0.00595	0.00464	0.0046	0.00584	0.00459
Cross Sectional Area	34 ft^2	62 ft^2	73 ft^2	39 ft^2	30 ft^2
Riffle Bed D_{84}	60.38 mm	51.69 mm	73.07 mm	51.69 mm	57.17 mm
Riffle Bed D_{50}	32.72 mm	29.96 mm	31.66 mm	29.96 mm	21.94 mm
Bar D_i (Max Particle Size)	55 mm	90 mm	90 mm	90 mm	65 mm
Bar D_{50}	8.11 mm	12.71 mm	12.71 mm	12.71 mm	8.38 mm
Avg. Meander Wavelength	183 ft	247 ft	300 ft	196 ft	172 ft
Sinuosity	1.22	1.2	1.19	1.2	1.24
Bankfull Slope	0.00486	0.00386	0.00387	0.00487	0.0037
Width to Depth Ratio	17.5	17.5	17.5	18.0	16.5
Bankfull Width (W_{BKF})	24.4 ft	32.9 ft	35.7 ft	26.5 ft	22.4 ft
Pool Width	30.6 ft	41.3 ft	44.8 ft	33.2 ft	28 ft
Bankfull Depth (D_{BKF})	1.4 ft	1.9 ft	2.0 ft	1.5 ft	1.4 ft
Riffle Max Depth	2.1	2.8	3.0	2.3	2.0
Pool Max Depth	3.7	4.9	5.2	4.1	3.6
Classification	C4	C4	C4	C4	C4
Sediment Transport Required Mean Depth	1.48 ft	1.83 ft	1.97 ft	1.45 ft	1.39 ft

<u>Construction</u>

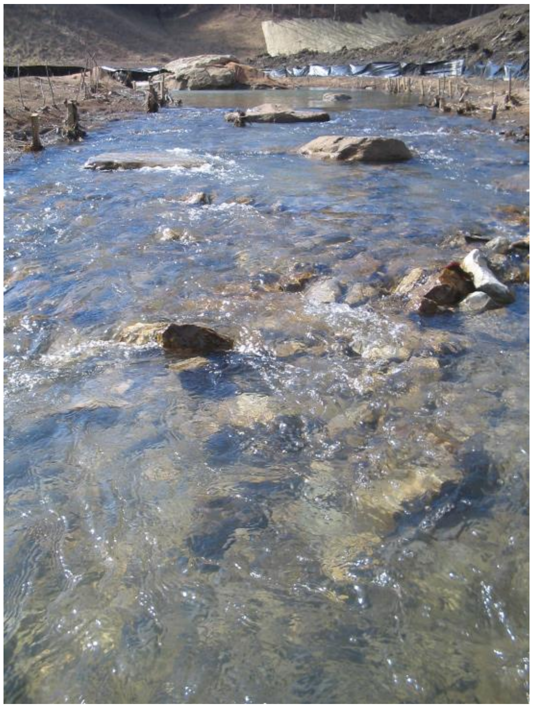
FMSM produced design drawings that were ultimately used by Enviro-Pro, Inc., the construction contractor. Construction commenced in December 2003 and follows the procedure outlined below:

- First, the floodplain was excavated at the design elevations and pattern using track hoe and a dozer.
- Next, the channel was excavated to the appropriate profile with the exception of pools at hydraulic structures as shown in Fig. 5. Riffle elevations were set using the maximum depth and shape according to the design drawings.
- Structures (J-hooks, log vanes and cross vanes) were installed at strategic locations. One of the goals of the project was a natural-looking stream; thus, the use of structures was minimized and wood was used where feasible. Structures were built "in the dry" to minimize

Figure 5. View of Lynn Bark After Excavation

Figure 6. Cross Vane on Lynn Bark

sediment. Fig. 6 shows a cross vane immediately after construction. Footing boulders were placed prior to the surface rocks. Rocks and logs used for hydraulic structures were stockpiled prior to construction to provide the contractor with an ample supply. Erosion control blanket was installed on both banks up to the bankfull elevation. The banks were covered with seed and straw prior to erosion control blanket installation. Straw matting was placed over all other disturbed ground. Live stake installation began in winter, 2004.



- Riffles were constructed using cobbles and gravel from the abandoned channel as well as material brought in from off-site. On steep riffles, boulder clusters like those shown in Fig. 7 were added to create converging and diverging flows aimed at dissipating energy. The stakes shown in this figure will be removed after live stakes are installed along the banks of Coldwater Fork and Lynn Bark.
- Construction is expected to be completed in the spring of 2004.

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