DRY CREEK ABANDONED MINE LAND RESTORATION DEMONSTRATION PROJECT: A COOPERATIVE EFFORT[1]

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Abstract: Historic coal mining that occurred on the Cumberland Plateau of middle Tennessee prior to the passage of the Surface Mining Control and Reclamation Act of 1977 left a lasting mark on the upland watersheds. Early exploration methods normally consisted of walking stream channels looking for coal outcrops. Where the outcrops were encountered, mining operations were started, often within the streambeds and advancing upstream and outward following shallow overburden cover. When these operations ceased they normally left open pits that became part of the stream channel. Acid forming material that was exposed during the operations oxidized and created pockets of standing and flowing surface water with depressed pH, elevated mineral content, and minimal aquatic habitat.

In 1999 Sequatchie Valley Coal Corporation (SVCC) and Tennessee Department of Environment and Conservation (TDEC) began discussions regarding acid rock drainage discharges from abandoned mine lands adjacent to the Sequatchie Valley Mine. A cooperative agreement was signed where restoration costs would be shared between SVCC, the TDEC Abandoned Mine Land Program, and the U.S. Environmental Protection Agency (EPA) through the Clean Water Act Section 319 Program. Work at the chosen site was to be demonstrative of accepted practices outlined in EPA's Coal Mining Best Management Practices Guidance Manual. Grubbing and clearing began in March 2002. Construction, which included diversion ditches, oxic alkaline addition channels, anoxic limestone drains, oxidation basins, and polishing wetlands, was completed in July 2002. Immediate improvement in the water quality of the receiving stream has been documented.

Additional Key Words:
Acid rock drainage, best management practices, cooperative agreement

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Introduction

Historic coal mining that occurred on the Cumberland Plateau of middle Tennessee prior to the passage of the Surface Mining Control and Reclamation Act of 1977 left a lasting mark on the upland watersheds. Early exploration methods normally consisted of walking stream channels looking for coal outcrops. Where the outcrops were encountered, mining operations were started, often within the streambeds and advancing upstream and outward following shallow overburden cover. When these operations ceased they normally left open pits that became part of the stream channel. Acid forming material that was exposed during the operations oxidized and created pockets of standing and flowing surface water with depressed pH, elevated mineral content, and minimal aquatic habitat.

The Dry Creek Abandoned Mine Land Restoration Demonstration Project is located on the Cumberland Plateau approximately 72 kilometers (45 miles) northwest of Chattanooga, Tennessee. The site was area surface mined in the 1960's, prior to the Surface Mining Control and Reclamation Act of 1977 (SMCRA). Prior to completion of the demonstration project, several open mine pits remained with impounded water and standing highwalls.

During the 1980's and early 1990's, Sequatchie Valley Coal Corporation (SVCC) operated a single seam, area surface mine adjacent to the project site. SVCC actively mined until 1992. Kennecott Energy Corporation acquired the SVCC property in 1993 and began backfilling and regrading operations. Revegetation was completed and Phase II bond release achieved in 1998.

In 1996 and 1998, the Tennessee Department of Environment and Conservation – Water Pollution Control (TDEC-WPC) agency conducted assessments to identify impacted surface waterways statewide. The Dry Creek watershed was identified in 1996 as being 'partially supporting' (siltation, pH, and metals as pollutant causes) and in 1998 as 'not supporting' (metals and habitat alteration as a result of abandoned mines) and was subsequently placed on the Tennessee 303(d) list. A 'high' magnitude rating, indicating severe impairment, was assigned by TDEC-WPC to the watershed.

Although the majority of the watershed (485 hectares) was mined and reclaimed under SMCRA, hundreds of hectares of abandoned, unreclaimed surface coalmines continue to impact the receiving stream either directly through discharge and runoff or indirectly through ground-water seeps. The upper tributaries, especially He, Big He, and Little He Creeks, as well as several smaller unnamed streams, of the Collins River-Dry Creek watershed receive the AMDrelated pollutants, siltation, high metal concentrations, and highly acidic waters from pre-law, unreclaimed surface coal mines as well as NPDES permitted discharges from SVCC operations.

The Cooperative Agreement

In early 1999, discussions began between SVCC, TDEC-WPC, and TDEC- Abandoned Mine Land (AML) Program regarding possible mitigation activities at the Dry Creek site. As the AML area and SVCC operation area were immediately adjacent to each other, it was difficult to identify and differentiate impacts from each area. An agreement was reached whereby mitigation work at the site was conducted under the Tennessee Nonpoint Source Program as a demonstration project for Best Management Practices as outlined in the Environmental Protection Agency's (EPA) Coal Mining Best Management Practices (BMPs) Guidance Manual (EPA, 2000). Costs of the demonstration project would be shared between SVCC (37.5%), EPA (37.5% as a section 319 project), and TDEC (25%).

The objectives of the project were primarily to:

1. Improve the water quality of two subwatersheds for the 303(d) listed Collins River – Dry Creek watershed through Tennessee's introductory utilization of BMPs delineated in the EPA Coal Mining BMP Guidance Manual (EPA, 2000) for land and water resource restoration and,
2. Demonstrate alternative NPDES permit criteria for the remining of coal at unreclaimed area (not contour strip) surface (not subsurface) mines that reflect practical levels while improving receiving stream water quality.

Although no removal of in-place coal reserves occurred during this 319 project, the use of BMPs, which would follow actual remining of this nature, was to occur at this pre-law (pre-1977) surface coalmine site. The BMPs included:

1. Construction of terraces (contour ditching) for diversion of surface water around AML spoils.
2. Reduction of highwalls, recontouring, alkaline addition, and revegetation of mine spoils and highwalls.
3. Construction of a series of alkaline drains and wetlands.

4. Construction of manganese oxidation systems immediately upstream of the discharge point.

Even though it was of much importance for this 319 project to improve the water quality of the receiving stream, it was equally important for this project to demonstrate to other mining companies that the use of remining BMPs will improve the water quality. Many other AMD receiving streams could be improved by implementing the prescribed BMPs of this project. By influencing others to help "carry the torch" of abandoned mine land reclamation, Tennessee hopes it might have a chance of successfully addressing most, if not all, of the highly impaired AMD watersheds within the state.

Design and Construction

Skelly and Loy, Inc. of Harrisburg, Pennsylvania prepared the conceptual designs for the demonstration project. The preparation of the designs required the assessment of the existing topography and vegetation, standing highwalls, and the water quality of contributed surface and groundwater. Accurate surface topography for the site was not available until the trees and vegetation were cleared. A pre-construction topographic survey was then conducted to provide a basis for cut and fill volume determination.

Skelly and Loy, Hedin Environmental, and SVCC had taken numerous flow measurements and samples for water quality analysis from collection points shown in Figure 1. Table 1 summarizes the analytical findings.

Table 1. Typical Historical Water Quality Data for Site

Station	pH*	Flow (gpm)	Total Acidity **	Total Alkalinity **	Total Iron **	Total Manganese **	Total Aluminum **	Sulfate **	Field Conductance ***
1	3.34	120	234	0	29.4	40.6	1.2	691	1465
2	3.16	95	182	0	35.1	41.3	1.6	695	1517
3	3.44	49	200	0	47.4	40.4	0.9	1193	1340
4	4.40	29	140	0	40.9	26.9	0.6	391	831
* Standard Units		** mg/L			*** us/cm				

The flow rate was variable and had been recorded at up to 23 L/sec (300 gallons per minute). For design calculations for the total system, an average total flow of 11.4 L/sec (150 gpm) was used. Other design assumptions were:

1. Average acidity was 166 mg/L
2. Iron concentration was 37 mg/L
3. Aluminum was < 1 mg/L in Anoxic Limestone Drain (ALD) areas
4. An ALD would produce 220 mg/L alkalinity (based on modified cubitainer results from prior testing (Schmidt and Stearns, 2001)).
5. 825 kilograms (12 tons) of limestone per L/sec (gpm) of flow would be adequate to provide maximum alkalinity generation (based on prior test information collected near the site).

The design information and material handling requirements were incorporated into a bid package. The bid package included the components listed in Table 2.

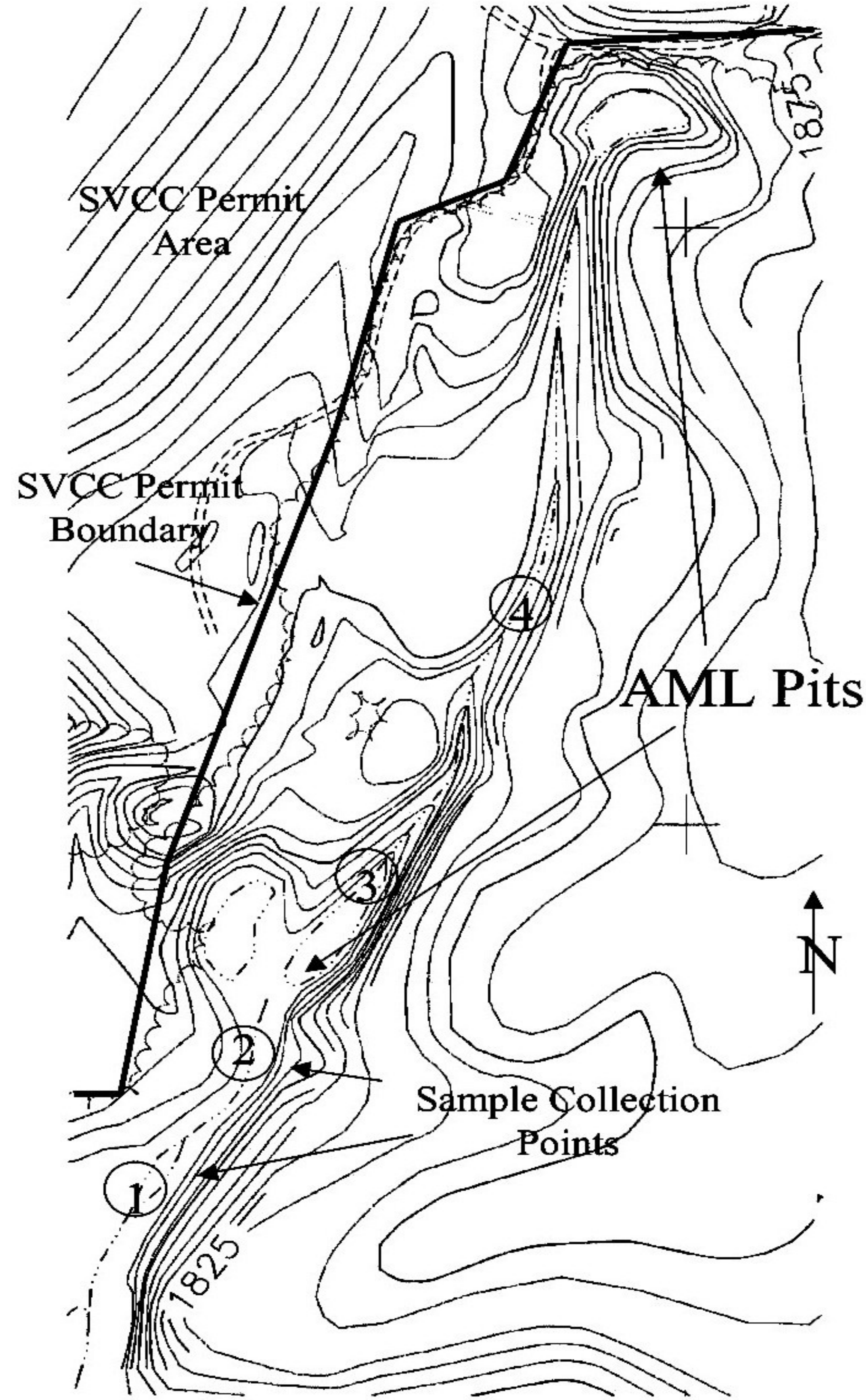

Figure 1. Pre-project Topography Scale: 1"= 250'

Table 2. Bid Package Components

Description	Quantity		Unit
Mobilization	1		Job
Quality Control	1		Job
Clearing and Grubbing	1.62		Hectares
Excavation and Embankment	1,529		Cubic Meters
Soil Placement Over ALD	1,147		Cubic Meters
Area Grading	1.62		Hectares
Ditches and Channels	518		Meters
Geotextile	1,923		Square Meters
Limestone			
d50=15 cm	453,600		Kilograms
d50=46 cm	907,200		Kilograms
Limestone Treatment	3,628,700		Kilograms
Pipe			
10 cm Schedule 40 PVC	146		Meters
15 cm Schedule 40 PVC	43		Meters
30 mil PVC Liner	1,254		Square Meters
Temporary Channel Liners	2,090		Square Meters
Vegetation Establishment	1.62		Hectares

Initial work at the site began in early March 2002 and consisted of grubbing and clearing of trees from the areas surrounding the proposed ALD sites. This work was done with track dozers and hoes to minimize the disturbed area and to facilitate piling of the trees. The trees were either left piled adjacent to wooded areas to provide wildlife habitat or burned.

Drainage ditches were excavated at each of the proposed ALD sites to allow as much of the impounded water to be removed as possible. By draining the pits, it was possible to visually determine where the majority of ground water was entering the pits. These areas were then targeted when constructing the ALDs to ensure that contact time with the limestone was maximized. Less sludge was encountered in the bottoms of the drained pits than was anticipated. This may have been primarily a result of the minimal amount of oxidation that occurred until the water began to travel through the drainage channel.

Crushed limestone for the ALDs (5 cm screened), diversions channels, and spillways (15 cm plus rip-rap) was acquired from a nearby (approximately 19 kilometers) quarry. Limestone was placed in the ALDs to a maximum elevation that was determined to be below the static ground-water elevation. By doing this, it was ensured that the limestone would remain in an anoxic condition.

As a result of not being able to determine the actual pit void volumes prior to the design phase and finding less sludge than was anticipated, we were able to place more crushed limestone in each of the ALDs than was proposed. Table 3 illustrates the conceptual design and actual amounts that were used. Figure 2 illustrates the as-built location of all structures.

Table 3. Crushed Limestone Usage (5 cm screened)

SITE	DESIGN MASS (kilograms)	ACTUAL MASS (kilograms)
ALD #1	453,600	1,691,900
ALD #2	680,400	990,650
ALD #3	680,400	2,519,250
ALD #4	Not Originally Planned	1,705,500
Total	1,814,400	6,907,300

The additional limestone amount was installed because of available space within the drained pits and will effectively extend the anticipated lifespan of the ALDs. ALD #4 was added during construction after an unanticipated seep was discovered during grubbing and clearing. Discharge piping was placed with air traps to ensure that air could not enter the drain. A 30-mil plastic cover was placed over the limestone to prevent oxygenated surface water percolation into the drain. A minimum of four feet of compacted earthen cover was placed over the drains to further ensure the limestone within the ALDs remained in an anoxic environment.

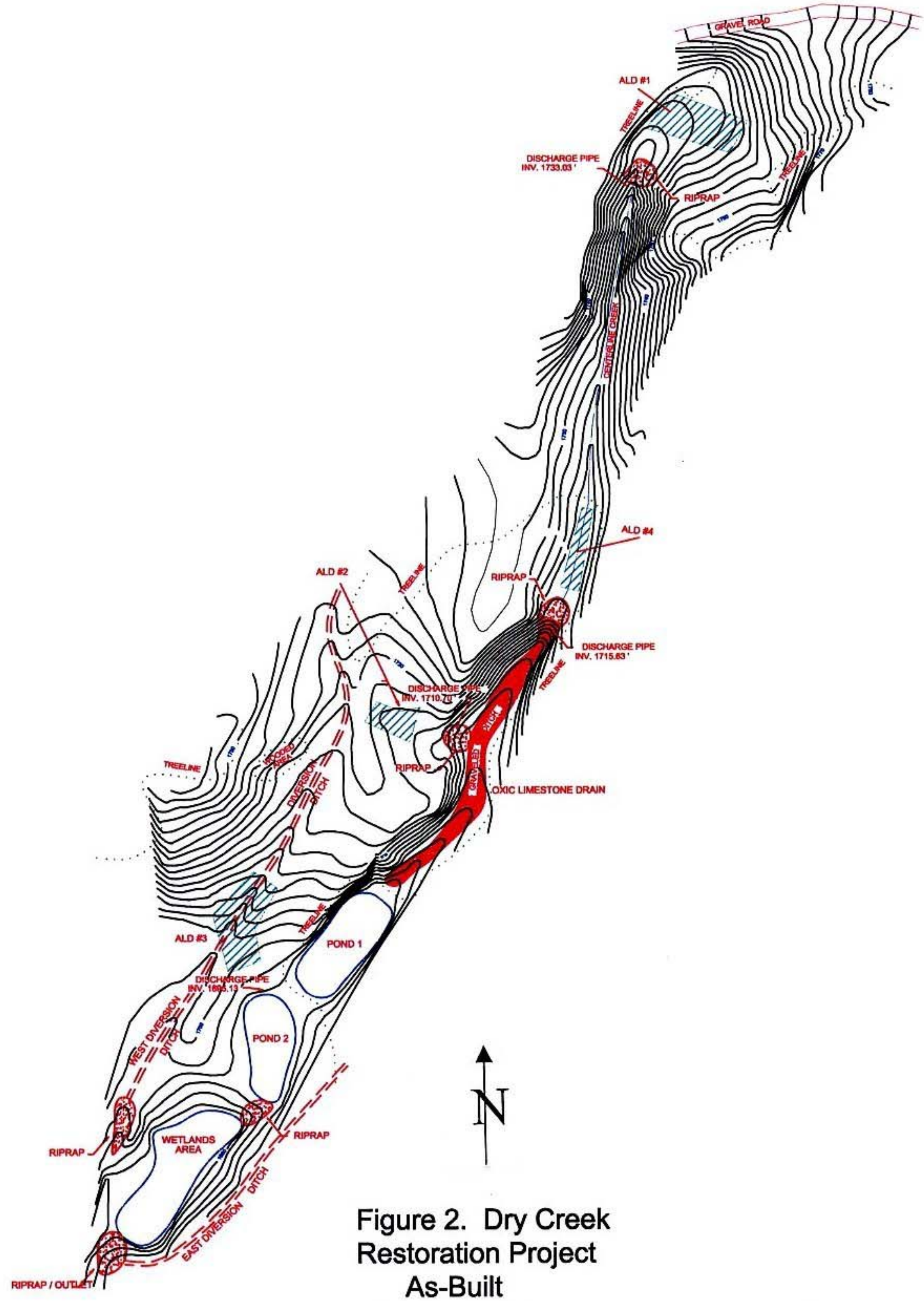

Figure 2. Dry Creek Restoration Project As-Built Scale: 1" = 250'

In addition to the 1,814,400 kilograms (2,000 tons) proposed for the ALDs, an additional 1,814,400 kilograms (2,000 tons) was proposed for the oxic limestone drains (OLDs). The OLDs serve as an additional stage of treatment and as a channel lining.

A 0.3 hectare oxidation pond was designed for this system to reduce iron concentrations from 37 mg/l down to approximately 10 mg/l. Two oxidation/settling ponds were constructed using existing depressions in the stream channel, excavated areas and small embankments. The pond sizes were maximized using available surface area. Pond 1, which has approximately 0.16 surface hectares, receives discharge from ALDs #1, #2, and #4, which combines in the oxic alkaline addition channel immediately upstream. Pond 2, which has approximately 0.12 surface hectares, receives discharge from ALD #3 and Pond 1. Discharge from Pond 2 flows through a riprap lined spillway into the constructed polishing wetland.

A polishing wetland was constructed as the final segment of the site. Leveling the channel bottom to ensure standing water was less than one foot in depth developed the constructed wetland, approximately 0.24 hectares in surface area. Organic material was incorporated into the fill material to provide a suitable rooting substrate for wetland vegetation. Straw was applied to the wetland surface to enhance microbe activity within the wetland. The wetland will be hand broadcast with on-site available wetland vegetation species during the winter of 2002 to enhance vegetation establishment.

Two surface water diversion ditches were constructed at the site to prevent the commingling of surface water runoff from the surrounding drainage areas and from within the site. The diversion ditches were constructed with minimal slopes to reduce flow velocities and were seeded and mulched upon completion. Straw bale check dams were placed in the ditches to provide sediment control until vegetation was established. The ditches discharged to the receiving stream via riprap lined outlet structures.

The West Diversion Ditch was constructed as a continuation of a pre-existing ditch that collected runoff from the adjacent SVCC mine reclaimed areas. The West Diversion Ditch, as constructed, varied from the original design due to strategic borrowing of fill material used in the covering of ALD #3. By borrowing material from the pre-existing highwall area and slightly adjusting the final location of the diversion ditch, we were able to reduce the slope of the middle portion, eliminating the need for a steeper sloped rock lined drop structure. The ditch was constructed to discharge into Dry Creek downstream of the constructed wetland outlet.

The East Diversion Ditch was constructed to collect runoff from a small-undisturbed drainage flowing east to west toward the wetland area. The diversion was constructed to discharge to Dry Creek at the wetland outlet.

The Results

Sequential samples were taken from the outfalls of each of the ALDs within the demonstration project and the outfall on November 13, 2002. The analytical data is compared in Table 4 with data from samples taken April 24, 2002 from the respective sites (except ALD #4 which was added later) prior to construction of the ALDs. The analytical data indicate that the ALDs are producing large amounts of alkalinity and subsequently increasing the pH of the wetland discharge. Aluminum and iron levels are higher than was anticipated in the design parameters. The elevated aluminum levels may require additional ALD maintenance. This may be offset at least partially by the use of additional tonnages of limestone in the ALDs. Vegetation within the wetland has not, as of November 2002, become well established. As this vegetation becomes more established it will assist in the removal of manganese and iron (Schmidt & Stearns, 2001).

Table 4: Water Quality on April 24, 2002 and November 13, 2002

	ALD #1		**ALD #2**		**ALD #3**		**Wetland**
	April 24, 2002	Nov. 13, 2002	April 24, 2002	Nov. 13, 2002	April 24, 2002	Nov. 13, 2002	Nov. 13, 2002
Flow (gpm)	N/A	18	N/A	11	N/A	30	61.6
pH	4.48	6.41	5.28	6.06	3.38	6.26	6.49
Total Alkalinity*	0.0	150.0	5.0	164.0	0.0	280.0	9.0
Total Acidity*	570.0	425.0	270.0	295.0	460	210.0	190.0
Total Iron*	213.0	180.0	115.5	57.5	63.2	131.0	15.3
Total Aluminum*	24.7	19.0	21.4	17.0	16.3	22.0	7.7
Total Manganese*	41.0	41.0	45.0	52.0	43.2	54.0	43.2

*mg/L

Samples taken from upstream, at the site discharge point, and downstream before project construction (11/14/00) and four months after project completion (11/13/02) are compared in Tables 5, 6,and 7, respectively. Flow measurements were not taken during the November 2002 sampling at the upstream and downstream sites but similar flow conditions to that of November 2000 may be assumed due to similar precipitation events. The data in Table 5 indicates that the 2002 flow immediately upstream of the discharge was similar to slightly improved quality compared to the 2000 sampling data.

Table 5: Dry Creek Upstream of Project Discharge Point

	November 14, 2000	**November 13, 2002**
Flow (gpm)	2,596	N/A
pH	5.51	6.5
Total Alkalinity*	8.0	8.0
Total Acidity*	16.0	10.0
Total Iron*	0.8	0.16
Total Aluminum*	0.04	0.02
Total Manganese*	0.66	0.12

*mg/L

The data in Table 6 are of samples taken from a flume located in the channel prior to construction and from the same flume relocated to the wetland outlet following construction. The reduction in flow can be at least partially attributed to the reduction of surface water input to the system resulting from the two constructed surface water diversions. The data shows a significant increase in pH and drop in acidity, iron, and manganese. There was an increase in aluminum that correlates with the higher than anticipated concentrations being discharged from the ALDs.

Table 6: Project Site (Wetland) Discharge

	November 14, 2000	**November 13, 2002**
Flow (gpm)	76	61.6
pH	2.85	6.49
Total Alkalinity*	0	9.0
Total Acidity*	270	190
Total Iron*	28.75	15.3
Total Aluminum*	2.05	7.70
Total Manganese*	47.75	43.2

*mg/L

The data in Table 7 are of samples taken approximately 50 yards downstream of the confluence of Dry Creek and the project tributary channel. The data is evident of improved water quality within the receiving stream. Only manganese levels are slightly elevated above 2000 levels.

Table 7: Dry Creek Downstream of Project Discharge Point

	November 14, 2000	November 13, 2002
Flow (gpm)	2,792	N/A
pH	4.91	6.38
Total Alkalinity*	4	10.0
Total Acidity*	19	5.0
Total Iron*	1.79	0.42
Total Aluminum*	0.12	0.11
Total Manganese*	1.6	1.98

*mg/L

In general, the Dry Creek restoration project is achieving the first project objective of reducing the input of metals to Dry Creek from the project tributary area. The limited amount of data currently available supports this. As the wetland vegetation develops, aluminum and manganese discharge levels will likely drop. The elevated aluminum discharge levels from the ALDs are a concern and will need to be monitored in the future to determine the impacts to the ALDs.

Current and future data gathered from this project should be invaluable in achieving the second objective of establishing alternative permitting criteria for the remining of coal at unreclaimed area (not contour strip) surface (not subsurface) mines.

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