LONG TERM EFFECTS OF ACID MINE DRAINAGEREMEDIATION PROJECTS ON STREAM QUALITY

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Introduction

In 1998 and 1999, water samples were taken in streams surrounding three acid mine drainage remediation projects in West Virginia. Based on the results, the remediation projects on each of these three sites were evaluated as to their effects on water quality. The three projects were the Webster Refuse AML Project in Preston County, the Douglas Highwall AML Project in Tucker County, and the Elk Creek Acid Mine Drainage Abatement Project in Barbour County. More remediation projects are being evaluated in this study, which is funded by the West Virginia Division of Environmental Protection, Office of Water Resources and the Office of Abandoned Mine Lands and Reclamation.

Webster Refuse Abandoned Mine Land Reclamation Site

The Webster Refuse site, located near State Route 26 about 5 miles south of Bruceton Mills, was about 35 acres in size. Three underground mine portals in the Upper Freeport Coal were discovered on the property and large piles of waste coal and gob were located immediately below the portals. A broken-down tipple was surrounded by the large piles of gob. Surface mining had been conducted along the contour, leaving a highwall of about 40 feet. Water from the portals and runoff water from the site drained into Webster Run. Webster Run flows into Little Sandy Creek, which then flows into Big Sandy Creek, and then into the Cheat River.

The West Virginia Division of Environmental Protection, Office of Abandoned Mine Lands and Reclamation initiated a project to reclaim this site. Construction was completed in the summer of 1988 by the Green Mountain Company at a cost of $519,333. The work performed on this project consisted of installing three non-calcareous gravel bulkhead mine seals, eliminating about 1,200 linear feet of highwall ranging between 20 and 50 feet high by excavation and backfilling, regrading mine spoil and coal refuse piles, constructing diversion ditches and rock underdrains, building a sedimentation pond, erecting a temporary acid mine drainage treatment facility, covering refuse and spoil materials with soil material, and establishing vegetation.

The most innovative aspect of the reclamation project involved the construction of an alkaline leach bed, a passive acid mine drainage treatment technique designed to treat water coming from the deep mine portals. The contractor was careful in the sequence of reclamation events because the bulkhead seals, the underdrains, and the leach bed had to be tied together at one time.

Water quantity and quality data from Webster Run, both above and below the alkaline leach bed, from the deep mine portals, and from the alkaline leach bed are given in Table 1. Webster Run above the AML project had a low pH and low acid concentrations before the project was initiated, and it has remained unchanged until the last couple of years. Our sampling in February 1999 showed almost no acidity in Webster Run above the project. The portal water has varied slightly over time from a pH of 2.9 to 3.9, and acidity from 60 to 300 mg/L as $CaCO_3$. The last sampling in February 1999 showed a much higher pH and lower acidity than those parameters as previously measured.

The alkaline leach bed has dramatically changed the deep mine water quality from acid to alkaline. It has raised the portal water from pH 3.0 to 7.5 and generated net alkaline water. The alkaline water from the leach bed has had a noticeable effect on Webster run downstream. In all cases since 8/88, the water pH increased and acidity decreased between downstream and upstream of the alkaline leach bed.

This leach bed is very large and contains much more limestone than would be normally used to treat an acid mine drainage flow of this size and magnitude. It has been extremely successful in treating the small quantity of water from the portals. It is expected to continue discharging alkaline water for many more years and has been a very successful passive acid mine drainage treatment method for this site.

Douglas Highwall Abandoned Mine Land Reclamation Project

The Douglas Highwall project is located along the North Fork of the Blackwater River between Thomas and Douglas on County Route 27 in Tucker County. The site was the location of the Davis Coal and Coke Company's cokeyards. It is not clear how many coke ovens were located within the project site, but a conservative estimate predicted more than one hundred ovens. The Western Maryland Railroad had an abandoned line which parallels the river. The track has been removed and the smooth, nearly level rail bed attracts hikers and all-terrain vehicle riders.

Highwalls for the Bakerstown coal seam were found along the southern edge of the property, located several hundred feet above the river bed on the contour. One very large and several smaller refuse piles were within the project boundaries. Many abandoned coke ovens were covered by the refuse, while a few were still visible at the time of project construction. At the upstream end of the project, the #29 underground mine portal was open and discharged large quantities of acid mine drainage directly into the North Fork of the Blackwater River. The amount of water coming from the portal varied between 3,000 to 100 gpm, and the water had a pH between 2.8 and 3.1, acidity concentration of about 300 mg/L as $CaCO_3$, Fe of 25 mg/L, Al of 30 mg/L, Mn of 7 mg/L, and sulfate of 550 mg/L.

Reclamation of the 60-acre site included excavating and regrading 360,000 cubic yards of spoil and refuse, and constructing subdrains along the base of the highwall which discharged water into several fabriform ditches to convey the water safely down the slope to the river. About 4,000 feet of highwalls were eliminated and five mine openings were closed. The innovative aspect of this project was the construction of a large bulkhead seal for the large #29 mine opening and piping about 250 gpm of the underground mine water to an experimental wetland/anoxic limestone drain (WALD) system to treat the water. The WALD was 2800 feet long, composed of two cells, with about 16,000 tons of limestone and 6,600 cubic yards of organic material. The entire project cost was $1.4 million.

Water quality data have been collected upstream and downstream of the reclamation activities on the site and also from the influent and the effluent of the WALD system. The acid mine drainage from the portal was introduced into the WALD starting in August 1994. Water quality data are shown in Table 2.

The WALD system raised pH of the 240 gpm flow from an average of 3.0 to a maximum of 7.3 during the first year (Table 2). After one year, effluent pH declined from 5.2 after 13 months (9/95) to 3.0 after 19 months (3/96). Effluent pH after approximately four years of operation has been about 3.5. Acidity decreased from 300 mg/L as $CaCO_3$ to an average net alkalinity of 127 mg/L as $CaCO_3$ during the first year. During the last three years, acidity values have averaged 169 mg/L as $CaCO_3$. Even though alkalinity is not measurable in the water, continued precipitation of metals in the system has caused a reduction in total acidity.

Iron and Al, the metals of primary concern, did not exit the WALD system during the first year and ferrous iron was not generated in the system by iron-reduction reactions. Manganese was also removed by the system during the first year and this was probably due to co-precipitation of the Mn with Fe and Al hydroxides. The pH and mV values measured in the wetland should not have been high enough for Mn precipitation by itself, but Mn is often reduced in treatment systems where Fe and Al are being precipitated.

The high mV and dissolved oxygen readings in water throughout the WALD system confirmed our observations of water flow in the system (data not shown). Most of the water flowed across the surface of the WALD in Cell I, rather than migrating downward through the organic matter. The low permeability of the organic substrate lead to short circuiting of the flow and little contact with organic matter was attained with the majority of the water. These data and our observations suggest that the Douglas WALD system acted as an aerobic, Fe-oxidizing system rather than an anaerobic, Fe-reducing system as originally intended.

After a few months of operation (in November 1994), we attempted to reduce the surface flow and encourage ponding and downward movement of the water into the organic substrate by installing a series of hay bale dikes every 10 m in Cell I. However without an outlet for the water below the limestone and organic substrate (such as a drainage system), the water simply ponded behind the dikes and exited at the dike's lowest point.

Although the effluent water quality was improved during the first year, the longevity of the system was compromised since Fe and Al in the water precipitated in the system. The system has not generated measurable alkalinity, but metals are continuing to precipitate in the system thereby reducing the acidity of the water and the metal load to the river. Assuming the average influent acidity value was 300 mg/L as $CaCO_3$ and the average effluent acidity value was 170 mg/L as $CaCO_3$ at the 240-gpm flow, an acid load reduction can be estimated. Approximately 158 tons of acid per year entered the river before treatment, while 89 tons of acid per year enter the river after passing through the WALD. This represents 69 tons less acid per year (or about a 44% reduction), and multiplying that amount for the past three years equals more than 200 tons of acid that have not entered the river. The system may continue to reduce the acidity of the water to this level for many more years. So while the system may not be introducing net alkaline water into the river, significant amounts of acid and metals are not entering the river due to the WALD system.

Elk Creek Acid Mine Drainage Abatement Project (Stewart Run Site)

In 1942, a railroad tunnel was constructed in the northern part of Barbour County. The tunnel intersected the old Berryburg underground mine (Pittsburgh Coal), which caused a continuous flow of acidic mine water to weep through the tunnel walls. This discharge forms the headwaters of Stewart Run, which then flows into Elk Creek of the West Fork River. At the time of the project, the area around the Berryburg mine was being surface mined by King Knob Coal Company (S-191-75).

The abatement project involved reducing the acidity in the mine water from the Berryburg mine in two ways: 1) an alkaline slurry trench was installed to form an impermeable barrier, which would inundate the old underground mine workings, and 2) alkaline overburden materials would be placed during surface mining into the area being inundated with water. The alkaline overburden was placed on the pit floor and the slurry trench was designed to retard water movement and potentially release alkalinity from the alkaline overburden for acid mine drainage treatment.

Trench installation was started in June 1978. The trench was dug about 2700 feet along the hillslope contour and a cement bentonite wall was installed along the downslope side of the trench. An outflow was placed at the lowest point along the slurry trench. Due to uneven coal pavement conditions, the slurry wall was not built as high as originally intended, thereby reducing the inundated area of the underground mine. Also, seeps developed upslope of the slurry trench, causing some soil sloughing. A riprap drainway was installed to divert surface runoff to reduce the soil sloughing problem. Further inspection revealed that the slurry trench did not impound water into the underground workings, but instead only served to direct subsurface water toward its lowest point where it overflowed into a pond. The cost of the project at Stewart Run was about $100,000.

Water sampling was conducted before and after the project. Table 3 contains data from Fred Moore's report (1989), and we recently extracted water samples from the same three sampling locations.

The water quality at all three sampling locations was between 3.1 and 3.3 and the water was net acid before the reclamation project. After construction of the trench and the mining activities, water quality during the 80-81 period downstream of the project showed higher pH (from 4.5 to 7.4) and net alkaline water (51 mg/L as $CaCO_3$ to 119 mg/L as $CaCO_3$ alkalinity). In 1986, a similar improvement in water quality was found as that of 80-81, indicating that the trench and alkaline overburden were still treating the acid water.

In February 1999, water quality in Stewart Run upstream of the project was very good (pH 7.7 and alkalinity of 15 mg/L as $CaCO_3$), and it improved slightly downstream as the water from the project entered the stream. It is clear from the data that the slurry trench and alkaline overburden placement had a dramatic effect on the water emanating from the slurry trench outflow. Stewart Run was also improved as a result of the abatement work.

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References

Moore, Fred S. 1989. Evaluation of the Elk Creek Acid Mine Drainage Abatement Project: Eight Years After Its Completion. Report on file at the West Virginia Division of Environmental Protection, Office of Water Resources, Charleston, WV.

Table 1. Water quantity and quality from Upper Freeport underground mines at the Webster Refuse abandoned mine land reclamation site. The alkaline leach bed has received the drainage from these deep mines since 1988 and water quality is given for water exiting the leach bed. Water quality is also given in Webster Run both upstream and downstream of the inlet of the alkaline leach bed water.

Location and Date	Flow	pH	Acid	Fe	Mn	Al	Sulfate
	cfs	s.u.	mg/L as CaCO3	---------------mg/L---------------			
Webster Run Above Leach Bed							
Jan-83	---	4.4	43	0.4	2.3	5.1	---
Aug-86	---	4.6	98	0.5	5.9	15	460
Feb-88	5	4.6	57	0.6	2.1	5.8	240
Aug-88	0.3	4.4	113	1.1	9	12.5	700
Feb-89	---	4.5	57	0.8	2.8	12	---
Aug-89	1.2	3.9	75	0.3	0.2	10.2	350
Jun-96	1.8	5.9	32	0.5	0.1	0.3	---
Feb-99	---	5.8	2	0.3	0.5	0.3	---
Portal Water							
Aug-86	---	3.7	129	2.4	3.3	7.7	1280
Feb-88	0.1	3.9	62	6.1	1.8	2.9	1000
Aug-88	0.1	3.3	140	14.5	4.8	17	1400
Feb-89	0.1	3.4	105	8	3	4.5	---
Aug-89	0.1	2.9	105	8	5.8	8	1280
Aug-92	0.1	2.9	290	9.2	3.8	10.8	1030
Aug-94	0.1	3.1	208	23	7.1	21.1	1040
Feb-99	0.1	5.6	15	0.6	1.3	0.2	---
Leach Bed Effluent							
Aug-88	0.2	7.7	-50	0.4	0.8	0.8	1000
Feb-89	0.1	7.1	-20	0	0	0.3	---
Aug-89	0.1	6.6	-40	0	0	0.2	1200
Aug-92	0.1	7	-65	0.1	0.3	0.5	1050
Aug-94	0.1	6.9	-127	0.1	1.1	0.4	1040
Feb-99	0.1	7.3	-89	0.1	0	0.3	---
Webster Run Below Leach Bed							
Jan-83	---	4.3	40	0.4	2	3.9	---
Jan-84	6	4.8	66	0.8	1.9	5.9	220
Aug-86	---	5.5	31	0.2	4.6	3.4	450
Feb-88	7	4.7	40	0.5	1.8	3.5	240
Aug-88	0.7	6.5	17	0.2	4.5	0.3	650
Feb-89	---	4.8	31	0.5	1.8	4.8	---

Aug-89	1.3	4.4	35	0.3	3	3.8	385
Sep-96	1.9	6.7	0	0.7	1.2	0.6	---
Feb-99	---	6	-5	0.3	0.5	0.3	---

Table 2. Water quality of the North Fork of the Blackwater River upstream and downstream of the Douglas and Albert AML Projects (including the WALD system at Douglas), and the water quality of the acid mine drainage going into and exiting the WALD over time.

Location and Date	Flow	pH	Acid	Fe	Mn	Al	Sulfate
	cfs	s.u.	mg/L as CaCO3	---------------	mg/L	---------------	
North Fork of the Blackwater Upstream of WALD							
Feb-94	31.9	7.1	-14	0.5	0.4	0.9	40
Aug-94	24.4	7.4	-19	0.7	0.3	0.6	41
Feb-95	2.1	7.2	-21	0.9	0.4	1	37
Aug-95	1.9	8.1	-34	0.8	0.3	0.3	60
Feb-96	19.1	7	-28	0.5	0.2	1.1	25
Aug-96	79.9	6.8	-18	1.2	0.2	0.7	22
Mar-97	10.5	6.9	-17	0.4	0.2	0.4	26
Sep-97	3.4	6.9	-40	0.3	0.2	0.1	77
Mar-98	45.8	7	-19	1.9	0.2	1.6	21
Jul-98	26.7	7.4	-28	0.7	0.2	0.6	24
Portal Water							
Jul-93	2.2	2.9	491	36.4	11.1	55.5	720
Apr-94	4.8	3	345	25	5.6	34.7	660
Aug-94	1.3	3.1	240	22	6.4	27.9	690
Feb-95	0.2	3	300	15.2	7.2	29.7	550
Aug-95	0.8	3.1	290	21	6.7	29.9	406
Feb-96	5	3	383	20.3	7	35.7	630
Aug-96	5.9	3	237	10	6.5	23	518
Mar-97	3.1	3	219	9.5	4.3	19.1	335
Sep-97	0.2	3	253	8.9	3.8	20.7	347
Mar-98	2.8	2.9	245	8.8	4.5	21.6	445
Jul-98	4.5	2.9	206	13.3	5.8	26.9	816
Sep-97	0.2	3	253	8.9	3.8	20.7	347
Water exiting the WALD							
Aug-94	0.5	7.3	-60	20	6	35	249
Nov-94	0.5	7	-231	0.30	0.2	0.3	625
Mar-95	0.5	6.8	-90	0	1.2	0.1	423
Jun-95	0.5	6.8	-120	0.2	14	1.5	395
Sep-95	0.5	5.2	-45	0.3	5.3	1.8	503
Nov-95	0.5	4.5	80	3.8	5.6	23.9	569
Mar-96	0.5	3	165	12.3	5.5	21	490

Jun-96	0.5	3.3	198		14	4.8	18.8	415
Mar-97	0.5	3	165		11.5	5.8	22.5	460
Nov-98	0.5	3.7	147		1.8	4.9	15.1	480
North Fork of the Blackwater Downstream of WALD								
Sep-91	22.5	3.5	100		12.12	.9	--	275
Sep-92	7.2	3.5	88		7.2	2	6.5	185
Feb-93	26.9	3.7	68		4	1.6	7.3	170
Jul-93	2.8	3.2	147		5.1	2.6	13.1	294
Mar-94	---	4.8		19	2.2	0.7	2.7	54
Feb-95	29.2	3.9	43		4.9	1.5	8	153
Aug-95	11.9	3.7	80		5.8	2.6	11.6	317
Mar-96	50.3	3.6	71		5.9	1.7	8.7	149
Aug-96	15.9	3.6	72		4.2	1.8	8.1	156
Mar-97	---	3.9		57	2.7	1.1	4.5	79
Sep-97	2.4	4.1	78		5.8	2.6	10.8	250
Mar-98	---	4.2		37	2.7	0.7	3.9	69
Jul-98	45.3	3.5	74		5.9	2.3	10.4	160

Table 3. Water quality of Stewart Run upstream and downstream of the slurry trench, and also the water from the slurry trench outflow.

Location and Date		Flow	pH	Acid	Fe	Mn	Al	Sulfate
cfs		s.u.	mg/L as $CaCO_3$		------------- mg/L			--------------
Stewart Run Upstream of the Slurry Trench								
Ave 10/73 -	12/77	0.3	3.1	319	29.0	6.7	8.6	1200
Ave 7/80 -	4/81	0.1	4.5	51	15.0	4.3	0.8	1000
Ave 3/86 -	10/86	0.3	4.5	41	7.1	6.4	5.2	1300
2/99		---	7.7	-15	0.5	0.7	0.4	---
Slurry Trench Outflow - constructed in 1978								
Ave 10/73 -	12/77	0.3	3.3	155	29	5.1	6.3	1400
Ave 7/80 -	4/81	0.2	5.6	-124	8.0	4.3	0.2	1300
Ave 3/86 -	10/86	0.2	7.9	-130	0.4	1.1	0.2	1400
2/99		0.1	8.3	-40	0.3	0.8	0.3	---
Stewart Run Downstream of the Slurry Trench								
Ave 10/73 -	12/77	1.7	3.2	56	9.0	3.3	4.4	850
Ave 7/80 -	4/81	---	7.4	-119	2.0	1.2	0.4	750
Ave 3/86 -	10/86	0.5	6.3	-30	2.6	4.9	4.1	1250
2/99		---	8.0	-20	4.0	0.8	0.4	---