SLIPPERY ROCK WATERSHED COALITION

SR96

Public Private Partnership Effort

Washington Township, Northern Butler County, PA

Stream Restoration Incorporated

A PA Non-Profit Organization 501(c)(3)
3016 Unionville Rd., Cranberry Twp., PA 16066
PH: 724-776-0161 FX: 724-776-0166 sri@salsgiver.com

Date: June 30, 2002

To: Bureau of District Mining Operations
Department of Environmental Protection
P.O. Box 669
Knox, PA 16232-0669

Attn: Tim VanDyke, Project Officer

Re: <u>SR 96 Final Report</u>
Project# NW90647; ME# 359746
Washington Twp., Butler Co., PA
200216/FR-trans

Enclosed is the final report for the above noted project.

The grant not only provided for the implementation of an innovative passive treatment system (Oxic-type Limestone Drain with limited flushing capabilities) but also provided for the continuation of the aquatic monitoring of the main branch of Slippery Rock Creek by students and faculty of Slippery Rock University. This "hands-on" educational opportunity has provided irreplaceable data regarding the impact of passive treatment systems on stream improvement.

This effort represents only a portion of the "success stories" associated with watershed restoration in the headwaters. The public-private partnership efforts continue to spur additional worthwhile projects in this and other watersheds in the region.

We hope that the final report will meaningfully acknowledge the importance of this project and the funding received through the PA Department of Environmental Protection Growing Greener Grant Program.

Please review and comment. The submission of a good quality work product is important to all of us.

From: Stream Restoration Incorporated

Margaret Dunn, PG; Tim Danehy, EPI; Shaun Busler, Bio.; Cliff Denholm, Env. Sci.; Deanna Treter, Office Mgr.

Sent: First Class Mail

Copy: Ron Stanley, Dir., DEP Grants Ctr.; David Hess, Sec., PA DEP;

SLIPPERY ROCK WATERSHED COALITION

SR96: FINAL REPORT

Slippery Rock Creek Headwaters
Washington Twp., Butler County, PA

"Making It Happen" through a Public-Private Partnership Effort

A Pennsylvania Growing Greener Watershed Restoration Project

Brief Description of Project Work through Grant and Partnership Contributions

- Completed applications and received permits/approvals.

- Installed approved Erosion and Sediment Controls.

- Designed and installed a passive treatment system for an acidic metal-laden discharge. Construction effort included installation of an Oxic-type Limestone Drain (700 tons limestone aggregate; 25-year design life) and enhancement of an existing AMD impacted wetland (about 1/6 acre). Extras to the original design include an underdrain with laterals extending the length of the drain with valved flushing capabilities and installation of about 150 feet of 18-inch N-12 piping to divert and to convey the overflow from an existing pond south of the drain. The existing well-established wetland was reconfigured with haybale directional barriers to increase retention time for formation and settling of solids. Design basis for the system used the "worst case" (raw water monitoring reported in PA DEP, Knox DMO, 1988, CMRS): 45 gpm flow, 3.4 pH, no alkalinity, 100 mg/l acidity, 25 mg/l iron, and 11 mg/l manganese.

- Continued monitoring of Slippery Rock Creek Watershed by Slippery Rock University students and faculty documented improvement from the passive systems on Slippery Rock Creek.

  DeNicola, D. M. and M. G. Stapleton, 2002, Chemical and Biological Monitoring of Slippery Rock Creek, PA Associated with Installation of Passive Treatment Systems to Treat Acid Mine Drainage for the Period Fall 1999 – Fall 2001: Final Report to PA DEP, 112 pp.

- Submitted scientific paper for publication:

  DeNicola, Dean M. and Michael G. Stapleton, 2002, Impact of acid mine drainage on benthic communities in streams: the relative roles of substratum vs. aqueous effects: Environmental Pollution, Elsevier Science Ltd., 13pp.

- Conducted tours; kept photographic log; submitted quarterly status reports and final report; administered the contract.

Grant Program and Funding: **Environmental Stewardship and Watershed Protection Grant (Growing Greener) - $50,000**

In-Kind/Matching: PA DEP, Knox DMO; PA DEP, BAMR; Slippery Rock University; PA Game Commission; Aquascape; BioMost, Inc.; Slippery Rock Watershed Coalition; Stream Restoration Inc. [non-profit]

PUBLIC-PRIVATE PARTNERSHIP

Water Quality Monitoring, Construction Inspection
PA Dept. of Environmental Protection, District Mining Office,
PO Box 669, Knox, PA 16232
GILLEN, Timothy, PG; BOWMAN, Roger, Engineer; PLESAKOV, James, MCI; ELICKER, Theresa, MCI; VanDYKE, Timothy, Insp. Supervisor; ODENTHAL, Lorraine, Permit Chief; CARLIN, Sherry, Watershed Manager; MIRZA, Javed, Dist. Mining Mgr. (814) 797-1191

Aerial Topographic Mapping
PA Dept. of Environmental Protection, Bureau of Abandoned Mine Reclamation,
RCSOB, PO Box 8476, Harrisburg, PA 17105
STEFANKO, John, Project Engineer (717) 783-1311

Landowner, Wildlife Management
PA Game Commission, PA Gamelands No. 95,
2026 West Sunbury Rd., West Sunbury, PA 16061
HOCKENBERRY, Dale, Land Mgr.; BRUNST, Chip, WCO (724) 637-3120

Environmental Assessment
Aquascape, 147 South Broad Street, Grove City, PA 16127
BERAN, Robert, Wetland Spec.; REIDENBAUGH, Jeff, Env. Eng.; SPENCER, Laura, Biologist; (724) 458-6610

Conceptual and Engineering Design of Passive Treatment Systems, Water Quality Monitoring, Operation & Maintenance
BioMost, Inc., 3016 Unionville Rd., Cranberry Twp., PA 16066
DANEHY, Timothy, EPI; DUNN, Margaret, PG; BUSTLER, Shaun, Biologist; DENHOLM, Clifford, Env. Scientist; TRETER, Deanna, Office Manager (724) 776-0161

Passive Treatment System Construction
Jesteadt Excavating, 528 Grindel Rd., Prospect, PA 16052
JESTEADT, Gerald, President (724) 865-2318

Limestone Aggregate
Quality Aggregates Inc., 200 Neville Rd., Neville Island, PA 15225
ALOE, Joseph, President; ANKROM, Jeff, Vice President (412) 777-6717

Aquatic Life and Water Quality Monitoring
Slippery Rock University, Slippery Rock, PA 16057
DENICOLA, Dean, PhD, Biologist, Biology Department (724) 738-2484

Grant Administration, Education and Public Outreach, Volunteer Effort
Stream Restoration Incorporated, 3016 Unionville Rd., Cranberry Twp., 16066
DANEHY, Timothy, EPI; DUNN, Margaret, PG; BUSTLER, Shaun, Biologist; DENHOLM, Clifford, Env. Scientist; TRETER, Deanna, Office Mgr.; TRETER, Chris, Intern; SHORT, Steve, OSM Intern (724) 776-0161

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SLIPPERY ROCK WATERSHED COALITION

SR96 RESTORATION AREA
WASHINGTON TOWNSHIP, BUTLER COUNTY, PA

A SLIPPERY ROCK CREEK MINE DRAINAGE ABATEMENT PROJECT
Slippery Rock Creek Headwaters

submitted to

Pennsylvania Department of Environmental Protection

EXECUTIVE SUMMARY

Participants in the Slippery Rock Watershed Coalition received funding from the Pennsylvania Department of Environmental Protection through the Growing Greener initiative to passively treat an abandoned mine discharge, to continue the biological and chemical monitoring of Slippery Rock Creek, and to provide public outreach and "hands-on" educational opportunities relating to watershed restoration.

The abandoned mine discharge, SR96, which has been successfully treated, demonstrates once again, how Public-Private Partnership efforts that include state agencies, private industry, nonprofits, and volunteers can work together to solve one of Pennsylvania's greatest lasting environmental legacies.

In order to effectively treat SR96, an innovative passive treatment system was installed that included a type of Oxic Limestone Drain and enhancement of an existing degraded wetland. The Oxic Limestone Drain was constructed with an underdrain system in order to provide a flushing mechanism to remove metal solids that potentially could decrease the hydraulic conductivity of the system.

Currently, the passive treatment system is neutralizing about 7 lbs/day of acidity and removing about 2½ lbs/day of metals. The system is also generating an additional 19 lbs/day of excess alkalinity. Preliminary data shows the improvement in water quality compared to the average raw (raw/treated): 4.5/7.5 pH, 7/112 mg/l alkalinity, 45/0 mg/l acidity, 11/3 mg/l iron, 4/3 mg/l manganese.

Based on recent and historical monitoring, the successful functioning of the SR96 passive treatment system is expected to eliminate 2600 lbs/yr of acidity and over 900 lbs/yr of metals from the receiving stream while adding an estimated 6900 lbs/year of excess alkalinity. This alkalinity is a significant contribution to the improvement of Slippery Rock Creek as downgradient untreated seepage would also be improved.

This project complements the nearby passive systems at SR81 (recently online) and SR89 (under construction) systems that were funded by a PA Growing Greener and US EPA 319 Funding/DEP mitigation, respectively.

COMPREHENSIVE TIMELINE

DEP Inspection
Tour
News Item

Date	Description
02/11/00	SR96 Growing Greener Grant submitted
03/20/00	Contract executed
09/21/00	Service Contract with Slippery Rock University executed
09/27/00	Service Contract with Slippery Rock University approved
11/15/01	Field Inspection
11/27/01	Grant extension requested
11/29/01	Grant extension approved
01/22/02	Environmental Assessment & Restoration Waiver submitted to PA DEP
03/14/02	Site inspection & water sampling
04/15/02	Restoration waiver granted by PA DEP
05/09/02	Preliminary draft sent to PA DEP Knox DMO for approval
05/14/02	Erosion & Sedimentation Control Plan sent to Knox DMO
05/26/02	Construction Phase begins with clearing & grubbing
05/29/02	Equipment on-site, tree removal has begun; DEP insp. (J. Pleskakov MCI) Road Bond Permit obtained through Amerikohl Mining Inc
06/04/02	Hay bale barriers in place; excavation for Oxic Limestone Drain nears completion; site inspection; water sampling; DEP insp. (J. Pleskakov, MCI)
06/10/02	Installation of underdrain system
06/14/02	Tour with Dr. Robert Nairn and his students from the University of Oklahoma
06/15/02	Site inspection
06/21/02	Hay bale directional barriers placed in wetland to divert flow and maximize retention
06/25/02	Site inspection; system discharging
06/28/02	Site inspection; water sampling
07/—/02	SRWC “The Catalyst” article “Construction Begins at SR96"

PROJECT DESCRIPTION

INTRODUCTION

In northern Butler County in western Pennsylvania, coal mining has been conducted in a 27-square mile area of the Slippery Rock Creek headwaters for over 100 years. Mining communities which were once bustling are now either abandoned or in decline, leaving only polluted streams, coal refuse, spoil, and highwalls. The residents that stayed called Slippery Rock Creek, "Sulfur Creek", due to the affects of mine drainage. In 1970 during the Commonwealth's Operation Scarlift, the quality of the headwaters was documented to be "the most severe condition of coal mine drainage…Indeed, very little drainage from this region is produced exclusive of contact with, or issuance from mine workings." (About 4,000 acres are underlain by mine workings and 8,000 acres were included in surface mine permits.) Within the 410 square miles of the Slippery Rock Watershed, streambed sediments in the headwaters have the highest heavy metal concentrations.

Since late 1994, the Slippery Rock Watershed Coalition has been working to restore the headwaters and has successfully completed thirteen abandoned mine restoration projects. As reported in the PA DEP, Knox District Mining Office (10/01) Slippery Rock Creek Progress Report: 2001, these systems have been about 100% effective in neutralizing acidity and 60 and 100% effective in reducing metal loadings. Also reported is that 11 miles of streams have been significantly improved.

As included in the attached report (DeNicola and Stapleton, 2002) that was completed through this grant, since 1995 long term increases in alkalinity have been observed, reflecting the combined restoration efforts. Also reported is that overall pH and alkalinity values are good, but temporary decreases in alkalinity with pH depression are noted during high flow, presumably through flushing of mine pools. This report also states, however, that despite extremely poor substrate, AMD sensitive taxa are beginning to be found in low numbers on hard strata.

Electrofishing surveys by Grove City College, Urban Wetland Institute, and SRWC volunteers have documented the presence of fish in at least 6 of the 11 stream miles improved.

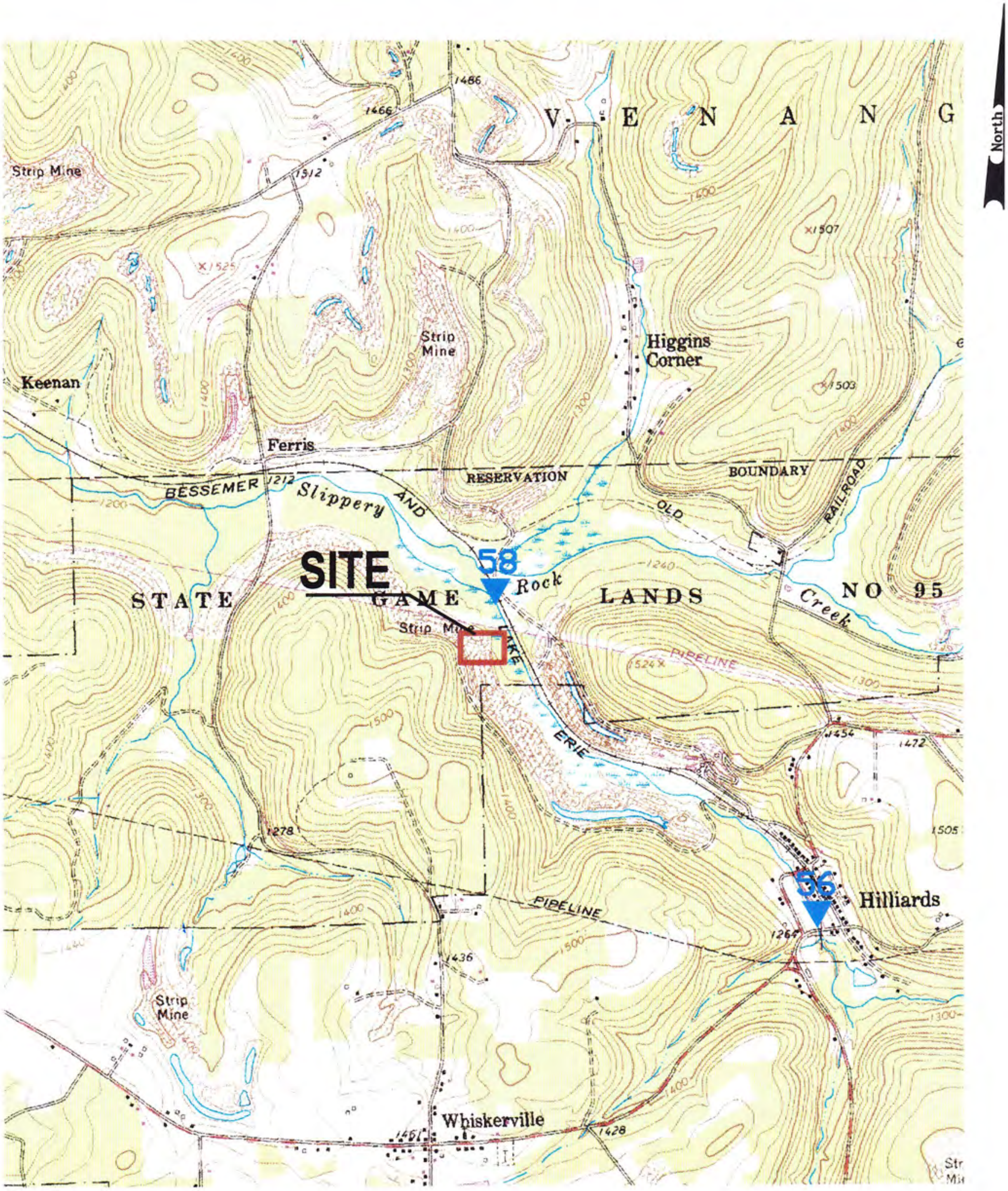
Based on the 1998 Comprehensive Mine Reclamation Strategy Report (CMRS) prepared by the Pennsylvania Department of Environmental Protection, Knox District Mining Office, the Hilliards Area, defined as Priority Area 4 is one of the areas most heavily impacted by pollutive drainage from abandoned coal mines in the headwaters. There are three major discharges located within the Hilliards Area that impact the Hilliards Branch of Slippery Rock Creek. These discharges are known as SR89, SR125B/D, and SR96.

A previous grant funded through the US Environmental Protection Agency 319 Program and construction services through a mitigation project are being utilized to address the

SR89 discharge. This final report addresses the SR96 restoration project, which was funded through the Commonwealth's "Growing Greener" initiative. Completion of these reclamation projects is estimated to improve approximately 3 miles of stream.

SR96 Site Location

SR96 is located within PA State Game lands No. 95 in Washington Township, Butler County approximately 1600 feet east off of Kolmyer Road and approximately 1 mile northwest of Hilliards, PA. The site is located on the 7 ½' USGS Hilliards topographic map (PR1977) at latitude 41° 05' 39" and longitude 79° 50' 60".



PROJECT LOCATION MAP: USGS 7.5' HILLIARDS, PA (PR 1979)

SLIPPERY ROCK CREEK - SR96

Slippery Rock Watershed Coalition

State Game Lands No. 95, Washington Township, Butler County, PA

***in cooperation with* Stream Restoration Incorporated**

May 2002, Scale 1 : 24,000

2000 1000 0 2000

BioMost, Inc., Mining and Reclamation Services
Cranberry Twp., PA 54/96LOC

PRE-EXISTING CONDITIONS

Extensive underground mining as well as surface mining of the crop coal on the Brookville coalbed (Clarion Fm.; Allegheny Gp.) resulted in an acidic metal-laden seep (SR96) emanating from a narrow breach in the spoil. Drainage from the seep flowed into and degraded a wetland before entering the “Hilliards Branch”, a tributary to Slippery Rock Creek. Large spoil piles with steep slopes severely limited the economically feasible area to build a passive treatment system. In addition, upgradient, good quality, impounded pit water overflows, at times, mixing with the SR96 discharge.

Representative Raw Discharge Characteristics

The following table depicts the quality of the SR96 drainage and the impact, from SR96 and other degraded discharges, on the quality of “Hilliards Branch” prior to installation of the passive treatment system:

Pre-Existing Average/”Worst Case” Stream and Drainage Characteristics

Point	Flow	pH	Acidity	Alkalinity	Fe	Mn	Al
SR96	18/45	4.5/3.4	44/100	7/0	12/25	4/11	<1
56 (upstream)	NA	6.5/6.1	1/6	24/12	<1/<1	<1/<1	<1/<1
58 (downstream)	NA	5.4/3.0	19/150	10/0	3/24	1/7	1/4

flow in gpm; alkalinity, acidity, and total metals expressed in mg/L; pH not averaged from H-ion concentrations; (Note the maximum flows do not necessarily correspond to maximum concentrations. See attached data.)

Pollutant Loadings from Untreated Discharge (Pounds per Year)

Point	Acidity	Iron	Manganese
SR96	2,600	700	250

Loading calculations based on PA DEP, 1998, CMRS

PASSIVE TREATMENT SYSTEM INSTALLATION

Site Preparation: Aquascape completed the Environmental Assessment and a wetland waiver was received. Road bonds and permits were handled by Amerikohl Mining, Inc. Passive system design plans were completed by BioMost, Inc., and reviewed by the PA DEP, Knox District Mining Office. Submission to the PA Historical and Museum Commission resulted in the response of "no registered sites". PA One Call relating to underground utilities was contacted and the response was no involvement. The Erosion and Sediment Pollution Control Plan was completed and mailed to the PA DEP, Knox District Mining Office and a plan was available on site and the facilities were installed.

Jerry Jesteadt, President, Jesteadt Excavating, had previously conducted site preparation activities in 1998 by removing a portion of spoil material and excavating a staging area as part of the SR101A EPA 319 grant. The remaining area for construction was then cleared and grubbed. Brush was placed in an area approved by the PA Game Commission.

The passive treatment system installed at SR96 consists of the following components in series **(See plans and photo section.)**:

1. Oxic Limestone Drain
2. Enhanced Wetland
3. Diversion

Bulk Materials: Limestone aggregate was used in the spillways and the Oxic Limestone Drain. The source of the aggregate is the Quality Aggregates Inc. Boyers Quarry, Boyers, PA. The Vanport limestone (Clarion Fm.; Allegheny Gp.), is a high calcium (90% $CaCO_3$) marine limestone.

Oxic Limestone Drain: In the original proposal, an Anoxic Limestone Drain was to be utilized as the primary passive treatment component; however, upon further field investigations, oxygen was found in seepage that would enter the passive system. The source of the oxygen in the discharge was most likely water from the pit impoundment mixing with or possibly causing seepage through the spoil breech. The presence of oxygen would encourage the precipitation of iron solids within this type of passive component. Accumulation of metal solids has been demonstrated to substantially reduce the hydraulic conductivity and the effectiveness of flow-through passive components. As Dr. Charles Cravotta, US Geological Survey, Lemoyne, PA has successfully installed Oxic Limestone Drains and as flushing of Vertical Flow Ponds has demonstrated that a significant portion of solids can be removed, an Oxic-type Limestone Drain was designed for this site.

Essentially the design of this Oxic Limestone Drain is the same as a typical Anoxic Limestone Drain with the primary difference being the inclusion of a flushable underdrain system. Geotextile was used to line the bottom and sides of the drain to the approximate elevation of the top of the limestone. The primary purpose of the

Geotextile is to decrease sediment from filtering into the drain. Approximately a 1/2-foot of AASHTO #57, 90% $CaCO_3$, limestone aggregate was then placed on top of the Geotextile as bedding stone for the underdrain system. Approximately 3½ feet of AASHTO #1, 90% $CaCO_3$, limestone aggregate was then placed on top of the underdrain system. Flushing events of very limited duration are planned. The system would be completely drained only during major maintenance.

As with the Anoxic Limestone Drain originally proposed, the primary function of the Oxic Limestone Drain is to neutralize acidity and produce excess alkalinity to precipitate metals within the wetland. Since oxygen is present within the discharge, recent flushing has demonstrated that some metals are precipitating within the Oxic Limestone Drain.

The underdrain was constructed of 4-inch, Schedule 40, PVC pipe. Perforated laterals were placed on 4.5-foot centers and connected to a solid header with a sanitary-type tee. Perforations were hand-drilled with two, 0.5-inch perforations approximately 30° from the top of the pipe. The perforation spacing was equal to the lateral spacing (4.5 feet). The header pipe extends from the treatment media through the breastwork to a 4-inch, slide-type gate valve. Prior to the gate valve, a “Y” was installed about midway through the breastwork to create a riser for the primary outlet.

Wetland: The Oxic Limestone Drain is followed by the wetland, which serves multiple purposes. The primary function is the settling of metal solids during normal operation and flushing. The wetland also provides wildlife habitat and additional water purification by the uptake, storage, and conversion of various pollutants.

Instead of excavating the existing natural wetland and constructing a new wetland, double-row hay bales were installed as directional flow barriers to substantially increase retention time and surface area contact to maximize treatment potential. From the wetland, the water enters the Hilliards Branch of Slippery Rock Creek.

Diversion: Originally an open channel was to be installed to convey the effluent from the abandoned surface mine pit impoundment. As originally proposed, the flow would have traversed the Oxic Limestone Drain. In order to minimize the potential for compromising the system and to provide for more accessibility for future maintenance, the pond effluent was diverted south of the Oxic Limestone Drain. Instead of an open channel, about 150 feet of 18-inch, N-12 culvert pipe was utilized to convey the pit pond effluent. The pipe discharges to a rip-rap stabilized outlet before entering the wetland.

PASSIVE TREATMENT SYSTEM PERFORMANCE

The passive treatment system at SR96 was only recently placed online (June 2002). The following discussion, therefore, is intended only as an evaluation of the initial performance.

WATER QUALITY THROUGH THE SR96 PASSIVE TREATMENT SYSTEM

Component	Flow	pH	Alkalinity	Acidity	Fe	Mn	Al
SR96	20	4.5	7	45	11	4	<1
OLD	14	7.7	144	0	9	3	<1
Wetland	14	7.5	112	0	3	3	<1

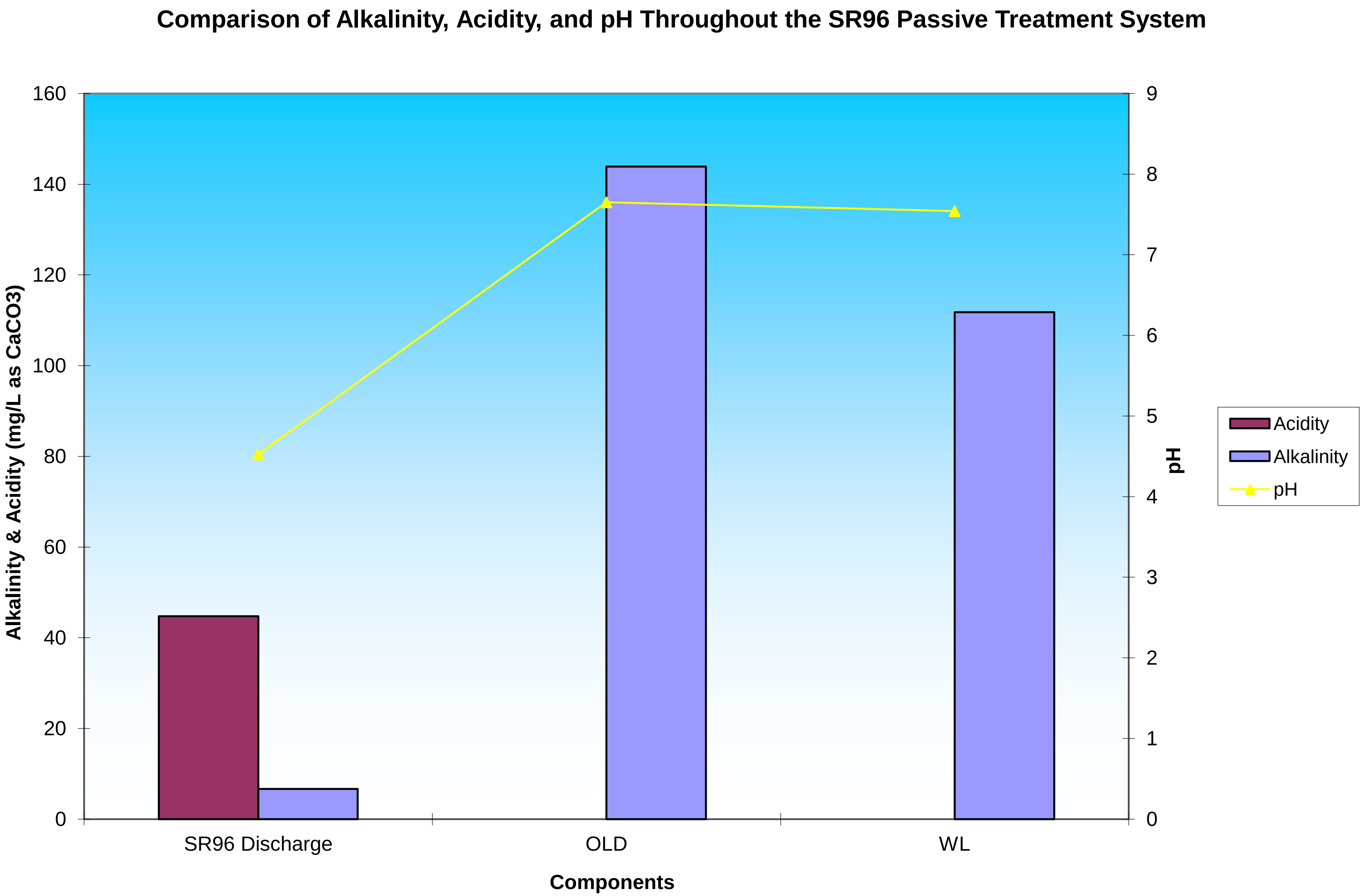
SR96 average pre-constuction raw water values; system sampling on 06/28/02; flow in gpm; alkalinity, acidity, and total metals expressed in mg/L; lab pH not averaged from H-ion concentrations (See attached analyses.)

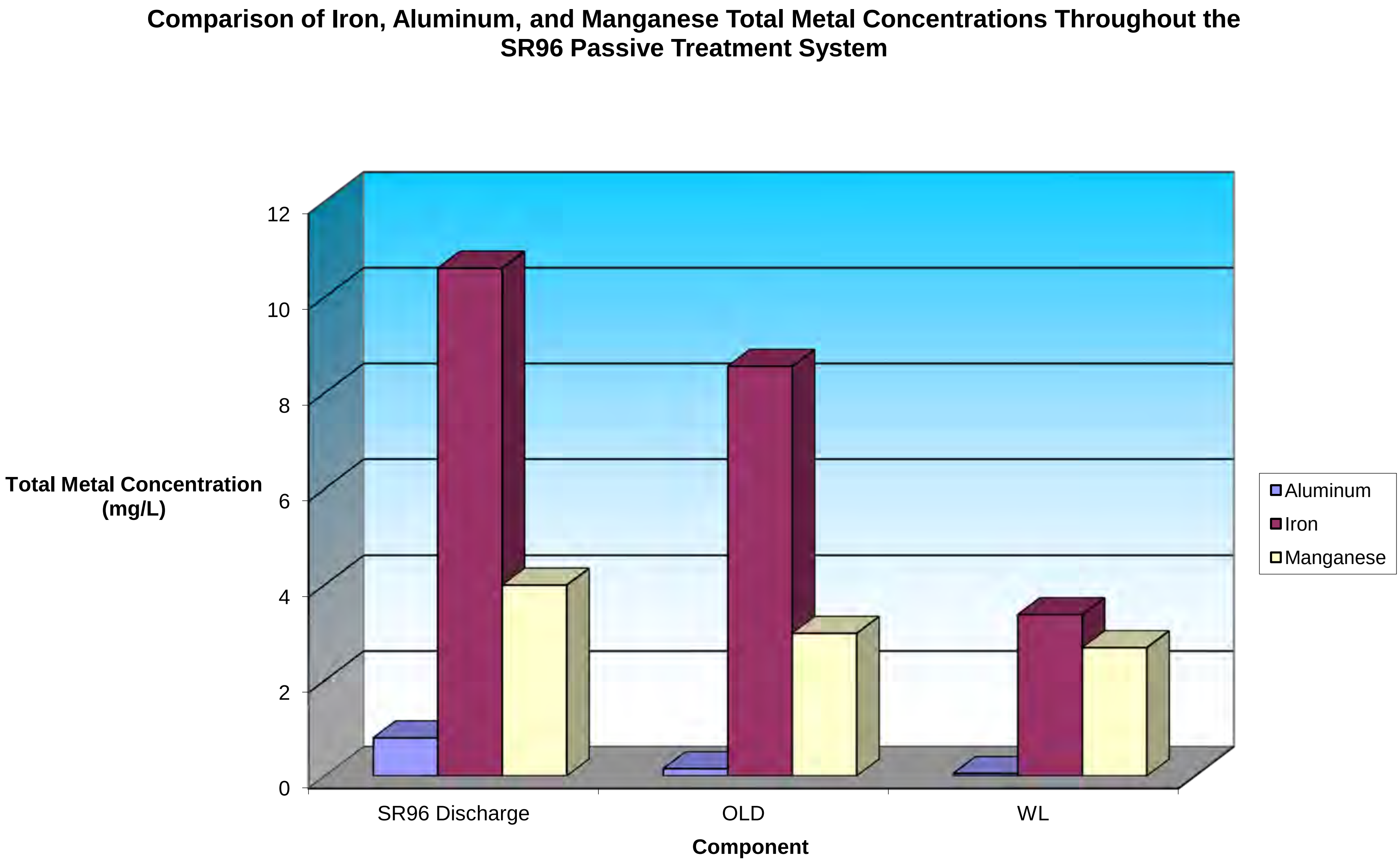
Oxic Limestone Drain: The Oxic Limestone Drain is successfully functioning with a performance comparable to Anoxic Limestone Drains that have been constructed in the Slippery Rock Creek headwaters. Influent to the Oxic Limestone Drain can be described as a net acidic, low pH, iron-laden discharge while the effluent can be described as a net alkaline, neutral pH, iron-laden discharge. Based on the average pre-construction raw water characteristics, currently 7 lbs/day of acidity are being neutralized within the system with an additional 24 lbs/day of alkalinity generated. During the first flushing, iron solids were observed to be removed from the system.

Wetland: The pre-existing wetland that was being impacted by the SR96 discharge was utilized as the treatment wetland. Double-row hay bales were staked to form the final barrier and two intermediate dircectional barriers to divert and to control flow direction and distribution in order to maximize retention time and fully utilize the available space in the existing wetland.

The wetland sample was taken at the end of the directional hay bale barriers. The water at this point is net alkaline with <3 mg/l dissolved iron, <3 mg/l dissolved manganese, and 0 mg/l dissolved aluminum.

Additional iron and manganese are expected to be removed prior to discharging to “Hilliards Branch” as the system effluent flows through additional wetlands prior to entering the receiving stream.


Comparison of Alkalinity, Acidity, and pH Throughout the SR96 Passive Treatment System
Alkalinity & Acidity (mg/L as CaCO3)
0
20
40
60
80
100
120
140
160
pH
0
1
2
3
4
5
6
7
8
9
SR96 Discharge
OLD
WL
Components
Acidity
Alkalinity
pH


Comparison of Iron, Aluminum, and Manganese Total Metal Concentrations Throughout the SR96 Passive Treatment System
Total Metal Concentration (mg/L)
12
10
8
6
4
2
0
SR96 Discharge
OLD
WL
Component
Aluminum
Iron
Manganese

SR96 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
SR96	11/1/1994				3.5				0	100	12.0		1.6				150	2
SR96	2/28/199	Measured	17		4.5				8	32	17.0		5.3		0.6		228	4
SR96	3/1/1995	Measured	45		4.8				9	28	5.2		1.8				61	3
SR96	3/30/1995	Measured	12		4.2				6	52	13.0		5.4				207	3
SR96	5/25/1995				5.9				14	6	1.5		0.2		0.6		36	9
SR96	7/27/1995	Measured	10		6.1				26	15	8.6		1.4				45	14
SR96	9/14/1995	Measured	10		3.5				0	86	25.3		10.1				262	8
SR96	0/12/199	Measured	11		3.5				0	92	24.6		11.0				275	24
SR96	11/2/1995	Bucket	9		3.4				0	74	17.5		10.2				338	3
SR96	5/23/1996	Measured	30		4.8				7	13	6.3		0.4		1.1		31	36
SR96	7/24/1996	Measured	12		4.2				5	54	15.3		5.7				227	
SR96	3/15/1996	Measured	12		4.3				5	58	17.8		6.9				210	
SR96	0/29/199	Measured	18		5.2				8	9	0.4		0.2				29	4
SR96	4/16/1997	Measured	30		5.6				9	4	0.9		0.2				34	
SR96	5/5/1999				4.0	301				87	4.1		3.1		0.8		130	3
SR96	3/14/2002	Bucket	25	5.0	4.9	144	5		3	6	0.1		0.3		0.9		73	7
Min			9	5.0	3.4	144	5		0	4	0.1		0.2		0.6		29	2
Max			45	5.0	6.1	301	5		26	100	25.3		11.0		1.1		338	36
Avg			19	5.0	4.5	223	5		7	45	10.6		4.0		0.8		146	9
Range			36	0.0	2.7	157	0		26	96	25.2		10.8		0.5		309	34

Description: Abandoned mine discharge SR96 emenates from a breach in the spoil.

SR96 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
56	0/19/199				6.6				30	0	0.3		0.1		0.5		37	3
56	1/31/1995				6.5				18	0	0.1		0.2		0.2		38	4
56	5/4/1995				6.7				18	0	0.3		0.2		0.5		47	8
56	7/26/1995				6.6				32	0	0.3		0.2		0.5		33	3
56	8/29/1995				6.5				36	0	0.3		0.1		0.5		66	3
56	9/27/1995				6.9				42	0	0.3		0.1		0.5		63	4
56	0/11/199				6.7				40	0	0.3		0.2		0.5		71	3
56	11/2/1995				6.4				32	0	0.4		0.3		0.5		64	3
56	2/12/199				6.3				20	0	0.3		0.1		0.5		36	6
56	1/25/1996				6.2				12	1	0.3		0.1		0.5		27	3
56	3/13/1996				6.3				13	0	0.3		0.1		0.5		35	3
56	5/16/1996				6.1				13	6	0.3		0.2		0.5		27	3
56	3/14/2002			6.6	6.7	148	10		12	0	0.1		0.1		0.5		45	6
Min				6.6	6.1	148	10		12	0	0.1		0.1		0.2		27	3
Max				6.6	6.9	148	10		42	6	0.4		0.3		0.5		71	8
Avg				6.6	6.5	148	10		24	1	0.3		0.1		0.5		45	4
Range				0.0	0.8	0	0		30	6	0.3		0.3		0.4		44	5

Description: Hilliards Branch; @ Bridge; Upstream of SR96 discharge

SR96 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
OLD	6/28/2002	Bucket	14	7.6	7.7	568	13	148	144	0	8.6	7.8	3.0	2.9	0.2	0.1	171	14
Min			14	7.6	7.7	568	13	148	144	0	8.6	7.8	3.0	2.9	0.2	0.1	171	14
Max			14	7.6	7.7	568	13	148	144	0	8.6	7.8	3.0	2.9	0.2	0.1	171	14
Avg			14	7.6	7.7	568	13	148	144	0	8.6	7.8	3.0	2.9	0.2	0.1	171	14
Range			0	0.0	0.0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0

Description: Effluent of the Oxic Limestone Drain

SR96 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
WL	6/28/2002			7.0	7.5	547	17		112	0	3.4	2.7	2.7	2.6	0.1	0.0	226	6
Min				7.0	7.5	547	17		112	0	3.4	2.7	2.7	2.6	0.1	0.0	226	6
Max				7.0	7.5	547	17		112	0	3.4	2.7	2.7	2.6	0.1	0.0	226	6
Avg				7.0	7.5	547	17		112	0	3.4	2.7	2.7	2.6	0.1	0.0	226	6
Range				0.0	0.0	0	0		0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0

Description: Effluent of the wetland

SR96 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
58	0/19/199				6.4				20	8	0.6		0.8		0.5		91	3
58	1/31/1995				6.4				16	5	0.2		0.4		0.1		45	2
58	5/4/1995				6.6				18	0	0.4		0.6		0.5		47	12
58	3/29/1995				3.0				0	150	24.4		6.9		4.4		343	22
58	9/14/1995				4.8				8	12	0.8		1.0		0.5		256	3
58	0/12/199				3.3				0	84	12.3		3.9		2.9		197	38
58	11/2/1995				4.1				4	22	4.8		2.0		1.2		136	4
58	2/12/199				6.0				13	8	1.4		0.6		0.5		100	4
58	1/25/1996				6.1				12	0	0.5		0.3		0.7		38	6
58	2/22/1996				6.3				12	12	0.6		0.4		0.5		34	3
58	3/19/1996				5.3				8	10	0.9		0.7		0.5		67	3
58	5/16/1996				5.5				10	30	0.9		0.4		0.5		72	3
58	6/26/1996				6.2				15	24	0.8		0.5		0.5		55	3
58	3/15/1996				5.3				9	13	2.9		0.9		0.6		129	
58	9/18/1996				5.9				15	6	1.0		0.3				42	
58	0/24/199				6.1				16	0	0.9		0.4				57	
58	2/19/199				5.6				10	4	1.0		0.4				52	
58	2/25/1997				5.9				12	6	0.5		0.3				53	
58	3/20/1997				6.0				12	2			0.4				40	6
58	4/15/1997				5.8				12	5	1.2		0.5				55	10
58	6/19/1997				5.6				9	7	1.7		0.8				71	
58	3/20/1997				4.4				6	24	3.6		1.6		0.9		139	4
58	9/17/1997				3.7				0	48	6.6		1.8		1.5		200	12
58	0/15/199				3.8				0	36	4.4		1.7		1.7		207	
58	2/11/199				5.8				15	5	0.9		0.4				57	

SR96 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
58	1/21/1998				5.7				14	2	0.9		0.4				50	
58	3/14/2002			6.4	6.6	180	11		11	0	0.2		0.3		0.9		59	8
Min				6.4	3.0	180	11		0	0	0.2		0.3		0.1		34	2
Max				6.4	6.6	180	11		20	150	24.4		6.9		4.4		343	38
Avg				6.4	5.4	180	11		10	19	2.9		1.1		1.0		100	8
Range				0.0	3.6	0	0		20	150	24.2		6.6		4.3		309	36

Description: Hilliards Branch; Downstream of SR96 Discharge before confluencing with

SR96 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
SR96-POND	5/5/1999				5.8	92			3	4	0.6		0.2		0.1		25	3
SR96-POND	6/5/2002			6.0	6.0	69	19		5	2	1.6	0.4	0.1	0.1	0.1	0.1	26	3
Min				6.0	5.8	69	19		3	2	0.6	0.4	0.1	0.1	0.1	0.1	25	3
Max				6.0	6.0	92	19		5	4	1.6	0.4	0.2	0.1	0.1	0.1	26	3
Avg				6.0	5.9	81	19		4	3	1.1	0.4	0.1	0.1	0.1	0.1	25	3
Range				0.0	0.3	23	0		2	2	1.0	0.0	0.1	0.0	0.1	0.0	0	0

Description: Water filled abandoned surface mine pit;

THE CATALYST

SLIPPERY ROCK WATERSHED COALITION MONTHLY ACTIVITIES UPDATE

<u>THIS MONTH'S MEETING:</u> Thursday July 11th at 7pm Jennings Environmental Education Center, pizza and pop will be provided.

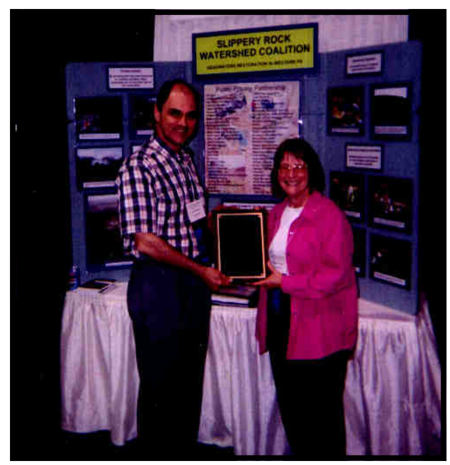
Dr. Robert Nairn Visits from Oklahoma with Some of His Students!!!

On Friday June 14, **Dr. Robert Nairn** and students from the University of Oklahoma toured the Slippery Rock Creek headwaters specifically to see the passive treatment systems. The graduate students included: **Denae Athay**, **Jennifer Coffey**, **Russell Garrett**, **Jessica Brumley,** and **Aisling O'Sullivan**. They were escorted on their tour by **Tim Danehy**, **Margaret Dunn**, **Cliff Denholm,** and **Shaun Busler** from Stream Restoration Inc., **Bob Beran** from Aquascape, **Dr. Fred Brenner** from Grove City College, and **Jeff Ankrom** from Quality Aggregates later joined the group and provided a wonderful outdoor picnic.

They toured the Sunbeam Tipple Site, SR 96 (where construction activities were described by **Jerry Jesteadt** of Jesteadt Excavating), SR 81, Erico Bridge, and Goff Station. The different components at each site were explained as well as the water quality data and construction issues. Thank you for making the long trip out here and taking an interest in our watershed reclamation efforts, your enthusiasm and interest were inspiring!!! Bob Nairn is an extra-special visitor, as he provided guidance on passive systems installed at Jennings.

SRWC Participant Receives Reclamationist of the Year Award

During the national meeting of **The American Society of Mining and Reclamation**, **Margaret Dunn** was presented with the 2002 Reclamationist of the Year Award. In the June 21st, DEP Update an article titled, "PA's Margaret Dunn Receives National Award," DEP Secretary **David Hess** is quoted as saying, "This national recognition for Margaret's work to build partnerships to clean up her watershed is well deserved." The article highlights both Margaret and the SRWC. Margaret feels this award further recognizes Pennsylvania's leadership nationally in abandoned mine restoration. **Joe Galetovic** from the Office of Surface Mining (OSM), was on the selection committee for the award. Pictured to the right are **Joe Galetovic** and **Margaret Dunn** with the award in front of the SRWC display at the conference. The conference was held in Lexington, KY from June 9th through the 12th. Good Job Margaret, We Are All Proud of You!!!!



Construction Begins at SR96

Construction of the 700 ton limestone drain recently began at the SR 96 site. On May 30th and 31st, OSM intern **Steve Short** (a biology student at Grove City College) staked 100 hay bales at the site for E&S Control. June 10th brought the actual construction of the drain. **Jerry and Jason Jesteadt** of **Jesteadt Excavating**, **Steve Short**, and SRI intern **Chris Treter** placed liners, spread limestone, and assembled the piping system. Thanks to Jerry and Jason Jesteadt for helping to build this system!!!!

On Friday June 21st, Steve and Chris placed 300 more hay bales as part of the wetland reconfiguration and during the week of June 24th they will be seeding, mulching, fertilizing, and more. Thank you Steve and Chris for all the back breaking work you both are doing!!!

PHOTO OF THE MONTH

PHOTO OF THE MONTH

The Butler County Juvenile Court System helps out with a wetland planting! Thanks!!!

The Butler County Juvenile Court System Plans to Help All Summer

This summer, the Butler County Juvenile Court System, will continue to provide extra help for wetland planting. Each Tuesday, from June 11 to August 27 they will work with Stream Restoration Inc., AquaScape, and Quality Aggregates, planting wetlands and helping with local Growing Greener projects. The Keystone Interventional Program (KIP), Community Intensive Supervised Probation (CISP) Program, and two local judges also plan to help with the planting activities. This is a unique opportunity for the participants to learn and enhance their own lives while assisting with environmental restoration.

Karns City Earth Day

On April 29th, **Bob Beran** and **Laura Spencer** of **Aquascape** participated in the **Karns City Elementary School Earth Day Activities**. Bob and Laura spent the day speaking to Kindergarten through 6th graders on insect biodiversity. The program, put together by staff at Jennings Environmental Education Center, provided the students with many laughs, interesting facts and information to fulfill educational curriculum needs. **Many thanks to: Jennings Environmental Education Center** for providing the power point program, as well as other learning tools, **PA DEP**, especially **Ms. Sherry Carlin**, for providing posters, bookmarks, and magnets for the students, and to **Mrs. Marion Hall** of **Karns City Elementary School** for inviting us to participate in their earth day activities!!

4th Annual AMD/AMR Conference

On June 14th and 15th, the 4th Annual AMD/AMR Statewide Conference took place at the Penn-Stater Convention Center in State College, PA. **Deanna Treter**, **Steve Short**, and **Chris Treter** represented the SRWC, introducing conference attendees to the reclamation work in our watershed and our recent publication, “Accepting the Challenge.” Seminars introduced conference goers to a variety of new treatment technologies and different forms of Operation and Maintenance for existing treatment systems. The highlight of the conference was a speech by PA DEP Secretary David Hess on Growing Greener and AMR Partnerships. Thanks to all those who attended and came over to learn more about the SRWC!!!!

Pennsylvania River Sweep

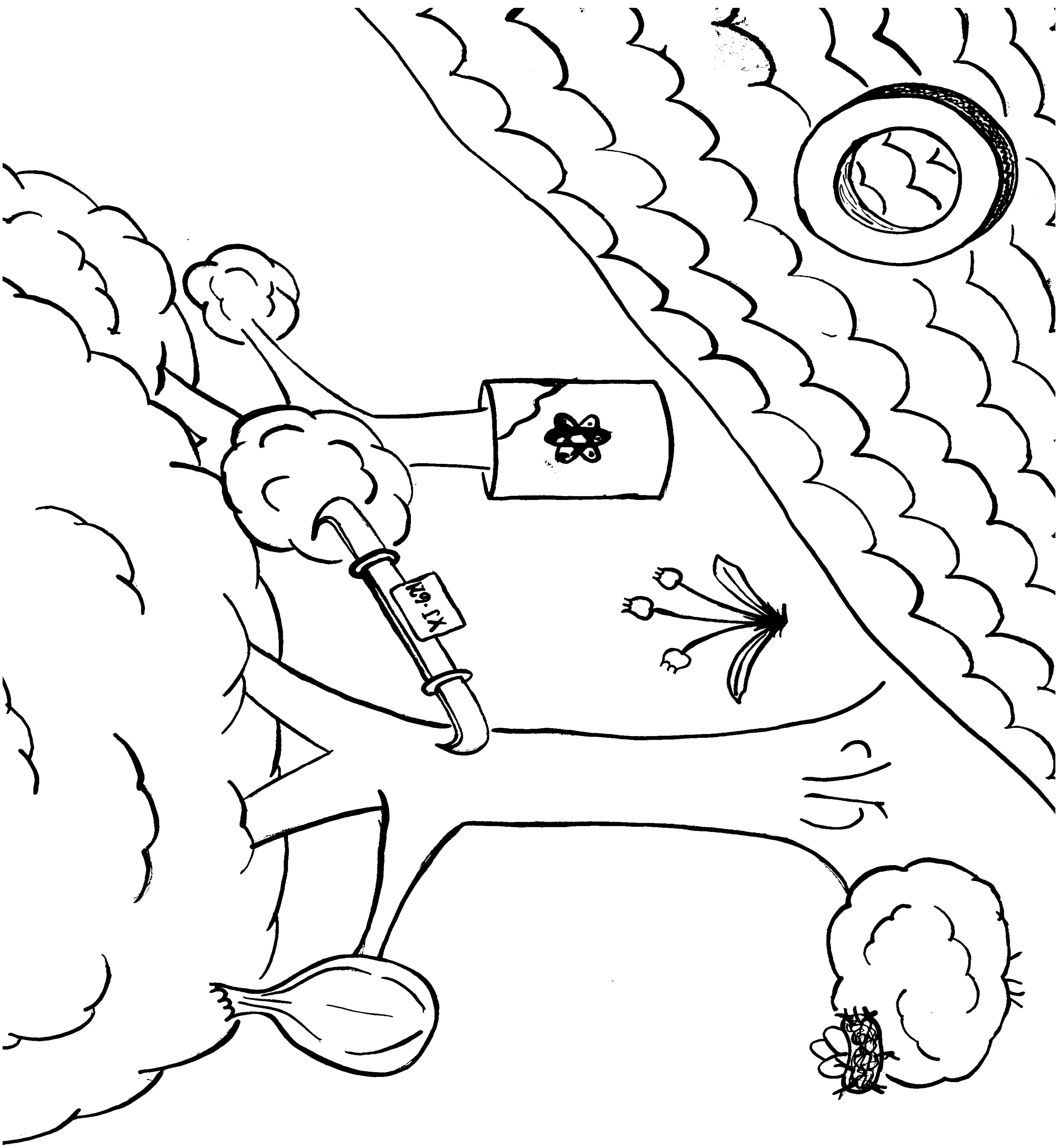
On Saturday June 15th, about 30 participants joined the statewide effort to clean our rivers. The participants, including **Shaun Busler, Melissa Busler,** and **Tim Danehy** of the SRWC, removed trash from the Blacks Creek Restoration Area located along Porters Rd., in Marion Twp. Those who were involved in this project include: **Marion Twp. Environmental Advisory Council, SRWC, PA Cleanways of Butler County, and Americorps.** A great time was had by all even though they got a little wet. Thanks to **Sheryl Kelly** and **Deb Bailey** for planning this extremely worthwhile project!!!

The KIDS Catalyst

SLIPPERY ROCK WATERSHED COALITION FUN ACTIVITY

River Seek and Find

Keeping our rivers clean is very important. When we do not properly dispose of our trash in a trash can it can harm some of the animals that call the river home. There are some things in this picture that don't belong. See if you can find them all, there are four of them. When you are done, color the picture and send it back to us for a free gift certificate. Good Luck, and remember to put your trash in the right place!



Name ________ Age ________ Address ________

The Watershed Academy Visits Our Watershed

On Thursday June 13th, the Watershed Academy visited our treatment systems at Goff Station and Erico Bridge. What is the Watershed Academy? Well, it is a program organized by the PA DEP and offers information about what watersheds are and some of the problems and issues impacting them. This year the program was held at **Jennings Environmental Education Center** in Slippery Rock. While at the sites, participants were given a tour and the different elements of the system were explained.

We have been asked to participate in the past and are pleased to once more be a part of such an informative day. Some of those providing the tour were: **Margaret Dunn** from **Stream Restoration Incorporated** as well as **Bob Beran** and **Maggie Allio** from **Aquascape.** In the picture to the left, Bob Beran is explaining restoration techniques to the group at Goff Station. Thanks to all those who attended! And a special thanks to those who helped make this such an informative trip!!!

Thank You Waste Management!

If you have ever witnessed or participated in a wetland planting, you may have noticed the way the plants are transported. Wetland plants are harvested and transported in recycling buckets donated by **Waste Management**. The buckets are sturdy enough to handle the rigors of containing heavy plant material while people carry them to and from the wetland. They provide convenience for wetland plantings as the plants can be grouped according to species and subsequently placed at appropriate water levels for the volunteers to plant. Without these buckets, harvesting and planting would be more difficult and definitely more costly (and probably less fun!!). We would like to give a very special thanks to **Jim David** and **Keith Bowser** of **Waste Management- Northwest Sanitary Landfill** for their very generous donation of buckets!

Thanks to The William & Frances Aloe Charitable Foundation, Amerikohl Mining, Inc., Quality Aggregates Inc., Allegheny Mineral Corporation and PA DEP for their support. For more information contact: Slippery Rock Watershed Coalition, c/o Stream Restoration Incorporated (PA non-profit), 3016 Unionville Road, Cranberry Twp., PA 16066, (724)776-0161, fax (724)776-0166, sri@salsgiver.com, www.srwc.org. July Distribution: 906 copies

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The acidic metal-laden SR96 discharge near its source.

The SR96 discharge flowing through the spoil breach.

Left: The SR96 discharge flowing through the spoil breach. Note the limited construction area and steep spoil piles.

Bottom: View of the abandoned pit impoundment left from past surface mining activities on the Brookville coal seam. During high flow periods and storm events, overflow from the impoundment would mix with the discharge.

Laura Spencer, biologist with Aquascape Wetland & Environmental Services conducting field work for the Environmental Assessment.

View of the vegetated spoil breech and source of the abandoned mine discharge during site preparation for the construction of the Oxic Limestone Drain passive treatment system.

A portion of the Oxic Limestone Drain during excavation. Note the coal seam along the bank.

Jerry Jesteadt, owner of Jesteadt Excavating, pumping out water that has collected within the sump for the Oxic Limestone Drain.

Jesteadt Excavating removing a portion of the spoil in order to construct the diversion channel around the Oxic Limestone Drain.

Jason Jesteadt installing the geotextile fabric before the limestone is placed.

Placement of the AASHTO #1 90% $CaCO_3$ limestone in the Oxic Limestone Drain by Jesteadt Excavating.

The underdrain flushing system for the Oxic Limestone Drain.

The outlet pipe from the Oxic Limestone drain, which will discharge into the wetland is located on the left while the flush valve and flush pipe is located in the center.

The drainage channel on the left is utilized to divert the flow from the pit impoundment around the buried Oxic Limestone Drain (Center).

Participants of the Slippery Rock Watershed Coalition included the SR96 project as part of their watershed tour given to Dr. Robert Nairn's environmental science students from the University of Oklahoma and Dr. Aisling O'Sullivan from the University College Dublin.

Following construction, agricultural lime was placed (above) before seeding and mulching (below) of the site.

Chris Treter, intern, spreading hay as mulch following seeding.

Tim Danehy and intern Steve Short, Stream Restoration Incorporated OSM intern, checking the alkalinity of the effluent of the Oxic Limestone Drain.

Double layered staked hay bales were installed by interns, Chris Treter and Steven Short. The hay bales are being used as flow diversion barriers to fully utilize the existing wetland.

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Impact of acid mine drainage on benthic communities in streams: the relative roles of substratum vs. aqueous effects

Dean M. DeNicola[a,*], Michael G. Stapleton[b]

[a]*Department of Biology, Slippery Rock University, Slippery Rock, PA 16057, USA*
[b]*Department of Environmental Geosciences, Slippery Rock University, Slippery Rock, PA 16057, USA*

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"Capsule": *Biological recovery of acid mine drainage-impacted streams is not significantly affected by metal residue on the substratum.*

Abstract

Restoration of streams impacted by acid mine drainage (AMD) focuses on improving water quality, however precipitates of metals on the substrata can remain and adversely affect the benthos. To examine the effects of AMD precipitates independently of aqueous effects, four substrata treatments, clean sandstone, clean limestone, AMD precipitate-coated sandstone and coated limestone, were placed in a circumneutral stream of high water quality for 4 weeks. Iron and Al were the most abundant metals on rocks with AMD precipitate, and significantly decreased after the exposure. Precipitate on the substrata did not significantly affect macroinvertebrate or periphyton density and species composition. In an additional experiment, percent survival of caged live caddisflies was significantly lower when exposed in situ for 5 days in an AMD affected stream than in a reference stream. Caddisfly whole-body concentrations of all combined metals and Fe alone were significantly higher in the AMD stream. Whole-body metal concentrations were higher in killed caddisflies than in live, indicating the importance of passive uptake. The results suggest the aqueous chemical environment of AMD had a greater affect on organisms than a coating of recent AMD precipitate on the substrata (ca. 0.5 mm thick), and treatment that improves water quality in AMD impacted streams has the potential to aid in recovery of the abiotic and biotic benthic environment.

1. Introduction

Acid mine drainage (AMD) from abandoned coal mines degrades more than 12,000 km of streams in the Appalachian Region of the Northeastern, USA, with 80% of the impacted stream miles located in western Pennsylvania and West Virginia (USEPA, 1997). The estimated cost of reclamation of watersheds affected by AMD in Pennsylvania is over $15 billion (Rossman et al., 1997). Acid mine drainage occurs when pyrite and other sulfide minerals associated with coal seams are exposed to water and oxygen. A series of chemical reactions results in mine water discharges that can be high in acidity and concentrations of metals. High acidity results from the oxidation and/or hydrolysis of Fe and other metals. At pH values of 2–3 in aerobic environments, acidophilic bacteria are the primary oxidizers of Fe, which then hydrolyzes and precipitates out of solution in copious amounts. At $pH > 5$, the abiotic oxidation of Fe^{+2} predominates. Ferric iron ions produced by the oxidation of pyrite are capable of dissolving other heavy metal minerals, which enter into solution at low pH (Singer and Stumm, 1970; Hedin et al., 1994; Mills and Robertson, 1995). When AMD runs off into more alkaline conditions in streams, dissolved metals such as Al, Zn, Cu and Pb precipitate, however these reactions are often out of equilibrium. Physical and chemical conditions in the sediment, and hydrology, also affect metal speciation and transport downstream (Boult et al., 1994; Broshears et al., 1996).

Decreased pH, increased concentrations of dissolved metals, and a high amount of metal precipitation (primarily iron hydroxide) caused by AMD runoff into streams usually result in drastic reductions in benthic macroinvertebrate abundance and diversity (e.g. Dills and Rogers, 1974; Letterman and Mitsch, 1978; Scullion and Edwards, 1980), and significant changes in

* Corresponding author. Fax: +1-724-738-4782.
E-mail address: dean.denicola@sru.edu (D.M. DeNicola).

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benthic algal communities (Verb and Vis, 2000). Concentrations of metals in benthic algae and invertebrates living in AMD contaminated sites are usually highly elevated (Gerhardt, 1993; Genter, 1996). Accumulation of metals in aquatic organisms is determined by the transport of dissolved metal species across external membranes, adsorption on body surfaces, and intake of particulate forms of metals (Hare, 1992). The degree of toxicity is determined by metal speciation, pH, hardness, uptake site, previous exposure, and differences among species in regulation (Gerhardt, 1993).

Many studies have suggested that precipitated forms of some metals, particularly iron, may be more detrimental to benthic communities than dissolved forms because precipitate can bury hard substratum and organisms (e.g. Warner, 1971; Hoehn and Sizemore, 1977; Letterman and Mitsch, 1978; McKnight and Feder, 1984; Gray, 1996; Verb and Vis, 2000). Moreover, the rate of recovery of streams following restoration of mine drainage inputs may be determined in part by the amount of residual insoluble, metal precipitate on the substrata (Chadwick and Canton, 1986; Nelson and Roline, 1996; Verb and Vis, 2000). While biomonitoring surveys can detect overall affects of AMD on benthic communities, there have been few experimental studies attempting to separate negative effects associated with aqueous and precipitate compartments (Gerhardt, 1992; Rousch et al., 1997), and none of these have been examined as possible limitations to recovery in treated streams.

Recent approaches to treating acid mine drainage involve installation of passive treatment systems, which rely only on gravity for energy, are relatively inexpensive to build and require minimum maintenance during their lifetime compared to active, mechanical treatment with chemicals. Most passive treatment systems divert AMD discharges through limestone in an anoxic environment to neutralize acid and increase alkalinity. The discharge then flows into an oxidation/retention pond or wetland where dissolved metals are allowed to precipitate leaving treated water to enter the stream. When correctly designed for the flow rate and chemistry of the discharge, passive treatment systems have been shown to be extremely effective in improving water quality (Hedin et al., 1994; Milavec, 2000). Theoretically, passive treatment systems are build to last at least 20 years, however longevity is affected by many site-specific factors such as water chemistry, hydrology, structural integrity of the limestone during dissolution, and bacterial processes (Hedin et al., 1994; Skousen et al., 1994). In this study, the first systems were built in the watershed in 1995 and have operated successfully to date.

Water and sediment chemistry, and benthic communities in Slippery Rock Creek in western Pennsylvania, USA have been monitored since 1995 to assess the recovery of the ecosystem due to extensive passive treatment of AMD. While there has been some improvement in the water quality in the headwater streams of Slippery Rock Creek as passive treatment systems have been installed, there has been little to no improvement in the benthic community (DeNicola and Stapleton, 1999). Our hypothesis was that recovery of the benthic community has not occurred because concentrations of metals in fine sediments remain high and coarser substrata continue to be coated with precipitated metals. The overall objective in the present study was to experimentally examine the degree to which substrata AMD effects were limiting recovery of benthic organisms in Slippery Rock Creek independently of aqueous conditions. Specifically our objectives were: (1) to determine whether cobble-sized substrata coated with AMD precipitate develop a different benthic flora and fauna than control substrata when placed into a stream unimpacted by AMD, and (2) to determine the loss of metals on substrata with AMD precipitate when placed in a stream with no mining impacts. We also compared the uptake of metals by filter feeding caddisflies from aqueous/food sources at an AMD site to that in an unimpacted stream in the watershed to assess aqueous AMD affects independently of substratum effects.

2. Study area

Slippery Rock Creek is a tributary in the upper Ohio River watershed of western Pennsylvania that drains an area of approximately 1100 km^2. The Slippery Rock Creek watershed has been severely impacted by AMD for more than a century, predominantly from coal mining activities in a 70 km^2 area at the headwaters. The headwater streams (1st–4th order streams) historically have had pH values in the range 3–6, iron concentrations as high as 100 mg l^{-1}, and contained an extremely low diversity of organisms (Academy of Natural Sciences, 1974). Since 1995, restoration of the headwater ecosystem has focused on extensive land reclamation and the building of 12 passive treatment systems. While water quality is substantially improved from 30 years ago, aqueous levels of dissolved metals can exceed USA and Pennsylvania water quality standards at certain times (Table 1), particularly during periods of high flow (DeNicola and Stapleton, 1999). In addition, concentrations of metals on the substratum remain high. As a result, macroinvertebrate densities are extremely low compared to nearby unimpacted streams (Table 1). While periphyton abundance can be high in AMD sites with sufficient light exposure, the flora is dominated by taxa characteristic of low pH (DeNicola and Stapleton, 1999). The unimpacted stream used as a reference in this study, Wolf Creek, is a productive 4th