SLIPPERY ROCK WATERSHED COALITION

FINAL REPORT: WATERSHED PROJECT

STREAM RESTORATION THROUGH COAL MINE DRAINAGE ABATEMENT Slippery Rock Creek Headwaters Project Cherry, Marion, Venango, Washington Townships, Butler County, PA

submitted to

Pennsylvania Department of Environmental Protection Bureau of Watershed Conservation

Brief Description of Project Work Conducted through Grant

Conducted a site evaluation including the installation of 13 piezometers to aid in the determination of the water table and seasonal fluctuations, subsurface water quality, and attitude of the Brookville Seatearth. Designed a 1 1/4-acre Wetland for an existing "kill zone", a Flush Pond, and a Vertical Flow Pond (innovative in design) to passively treat the SR89 discharge which averages 50 gpm, 3.1 pH, 260 mg/l acidity, 60 mg/l iron, 5 mg/l manganese, and 9 mg/l aluminum. Completed and received approval on permits and site notifications including the Environmental Assessment and PNDI. Monitored streams in 27-sq. mi. Slippery Rock Creek headwaters area. Expanded the public-private partnership effort. Compiled analyses and presented data during site tours and at annual Slippery Rock Watershed Coalition Symposia and other conferences locally, regionally, and nationally since 1996.

Contract Number & Amount: ME#358079; \$108,529

Grant Program:

FY98 US EPA Section 319 NPS

Administered by:

Stream Restoration Inc.[Non-Profit (501(c)(3)]

In-Kind Contributors: Slippery Rock University PA DEP, Knox District Mining Office PA DEP, Bureau of Abandoned Mine Reclamation Grove City College PA Game Commission PA Fish and Boat Commission Seneca Landfill, Inc. Slippery Rock Watershed Volunteers BioMost, Inc. Stream Restoration Incorporated

December 2001

cover photos: (upper) "Kill zone" below abandoned mine discharge SR89 (09/2001) (lower) delivery of limestone aggregate for passive treatment system (12/2001)

PUBLIC-PRIVATE PARTNERSHIP

Stream Monitoring

Slippery Rock University, Slippery Rock, PA 16057 DeNICOLA, Dean, PhD, Biologist, Biology Dept. (724) 738-2484

Stream and Discharge Monitoring

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

Aquatic Life Monitoring (Seaton Creek tributary)

Grove City College, Grove City, PA 16127 BRENNER, Frederick, PhD, Biologist, Biology Dept. (724) 458-2113

Landowner Consent and Revegetation Assistance

PA Game Commission, Game Lands 95, 2026 West Sunbury Rd., West Sunbury, PA 16061 HOCKENBERRY, Dale, Land Manager (724) 637-3120

Passive Treatment System Design

BioMost, Inc., 3016 Unionville Rd., Cranberry Twp., PA 16066 DANEHY, Timothy, EPI; DUNN, Margaret, PG; BUSLER, Shaun, Biologist; DENHOLM, Cliff, Env. Sci.; FUNKHOUSER, Deanna, Communications (724) 776-0161

Construction Services

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Jesteadt Excavation, 528 Grindel Rd., Prospect, PA 16052 JESTEADT, Gerald, President (724) 865-2318

Seneca Landfill, Inc., PO Box 1080, Mars, PA 16046 VOGEL, Edward, Vice President (724) 625-1511

Youchak & Youchak, Inc., 932 West North Ave., Pittsburgh, PA 15233 YOUCHAK, Michael, PE (412) 323-8840

Environmental Assessment

Aquascape, 147 South Broad St., Grove City, PA 16127 BERAN, Robert, Dir.; REIDENBAUGH, Jeff, Eng.; SPENCER, Laura, Biologist (724) 458-6610

Piezometer Installation

BioMost, Inc., 3016 Unionville Rd., Cranberry Twp., PA 16066 DANEHY, Timothy, EPI; DUNN, Margaret, PG (724) 776-0161

Aerial Topographic Mapping

PA DEP, Bureau of Abandoned Mine Reclamation, RCSOB, PO Box 8476, Harrisburg, PA 17105 STEFANKO, John, Project Engineer (717) 783-1311

Construction Assistance

PA Fish & Boat Commission, 450 Robinson Lane, Bellfonte, PA 16823 KEPLER, Steve, Biologist (814) 359-5117

Grant Administration and Volunteer Effort

Stream Restoration Incorporated, 3016 Unionville Rd., Cranberry Twp., 16066 DANEHY, Timothy, EPI; DUNN, Margaret, PG; BUSLER, Shaun, Biologist; DENHOLM, Cliff, Env. Sci.; FUNKHOUSER, Deanna, Communications (724) 776-0161

CONTENTS

<u>Summary</u>

Project Summary Timeline

<u>Photos</u>

<u>Area Map</u>

Target Area Map (pocket - 1 sheet)

Site Evaluation

SR89 Site Evaluation Reference List Piezometer Logs Water Sample Analyses

<u>Design</u>

Design Narrative Design Sheets (pocket - 3 sheets)

Environmental Assessment

Restoration Waiver - DEP EA 10-016NW (06/26/01) Environmental Assessment (05/08/01) **Executive Summary Environmental Assessment Form** Wetlands **Project Location Description of Aquatic Habitat Project Description** Maps Site Map Soils Map National Wetlands Inventory Map Wetland Area Map Photos List of Plant Species Wetland Water Quality SR89 Water Quality Notifications and Reviews US Fish & Wildlife Serv., Threatened/Endangered Species (10/30/00) PA Fish & Boat Comm., Secondary Species Impact Review (03/01/01) PADCNR, Bureau of Forestry, PNDI (10/10/00) PHMC, Historic & Archaeologic Resources (10/25/00) Butler County Commissioners notification (04/23/01) Washington Twp. Supervisors notification (04/23/01)

FY98 EPA proposal (Rev. 4/98)

Slippery Rock Creek Headwaters Project Butler County, PA

12/2001 103001

PROJECT SUMMARY

For over a century the Slippery Rock Creek headwaters has been heavily impacted by abandoned coal mining activities. The US EPA Section 319 NPS program has enabled participants in the Slippery Rock Watershed Coalition to develop public-private partnership efforts to provide long-term, low-maintenance treatment of degraded discharges and to monitor the recovery of the streams. By combining this effort with Pennsylvania's Growing Greener and Reclaim PA, over 500,000,000 gallons annually are being successfully treated with documented improvement in 11 stream miles (PADEP, Knox DMO, SRC Watershed Progress Report: 2001). Stream monitoring has been conducted by students and faculty of Slippery Rock University and Grove City College. Including the passive system being built through this grant, seven Anoxic Limestone Drains, fourteen Vertical Flow Ponds, eleven Settling Ponds, twelve Wetlands, and three Horizontal Flow Limestone Beds have been or are in the process of being constructed in the headwaters. This grant, in addition to the stream monitoring program, enables the construction of a passive system to treat the discharge known as SR89. Until the installation of an innovative Vertical Flow Pond in 1997 at the Jennings Environmental Education Center (also completed through EPA 319 funding), SR89 was considered essentially untreatable by passive methods due to the severely degraded water quality (3.1 pH, 260 mg/l acidity, 60 mg/l iron, 9 mg/l aluminum). Nonetheless, eliminating the degradation at SR89 is imperative to the restoration of the main branch of Slippery Rock Creek as this discharge contributes the fourth highest acid (136 lbs/day) and iron (32.4 lbs/day) loadings. To the tributary known as the Hilliards branch, SR89 contributes 79%, 93%, and 63% of the acid, iron, and aluminum load, respectively. Due to difficult site conditions, including the lack of change in elevation, confined water-bearing zones and fluctuating water table, the presence of severely degraded wetlands ("kill zone") and a spoil mound, coupled with the proximity of two lakes, a utility line, and a railroad grade (until recently owned by others), additional partners were needed in order to utilize the latest technology with the greatest opportunity for success. With assistance from the PADEP, Knox District Mining Office and Bureau of Abandoned Mine Reclamation, PA Fish and Boat Commission, and Seneca Landfill, Inc., an innovative (possibly the only one of this design) Vertical Flow Pond is being constructed. Seneca Landfill provided drilling services for the installation of 13 piezometers and is excavating about 40,000 CY (rough estimate) of spoil, iron sludge, and other material in order to construct the Vertical Flow Pond (2100 tons of AASHTO #1, 90% CCE, limestone aggregate), 1,500 CY Flush Pond, and 1 1/4-acre Wetland. In-place clay material below the extensively mined Brookville coalbed will form the gently sloping (~2%) bottom of the Vertical Flow Pond. A two-tier underdrain system for flow distribution and flushing purposes will be installed in this facility. In the area of the current "kill zone", a treatment wetland will be constructed. Permits/approvals have been received and system designs have been reviewed by the PADEP Knox DMO. Construction materials are onsite or stored at Stream Restoration Inc. Installation of the system is expected to be completed within the next few months with the wetlands planted during the summer. Based on the results of other systems installed in the headwaters, this facility is expected to be 100% effective in removing the acidity and aluminum and 60 to 100% effective in removing the iron.

TIMELIN SELECTED EVENTS

Date 1996/07/25 1996/10/16	From CDS PADER, BLWC	To PADER, BLWC CDS	Description FY98 EPA Funding Request FY98 EPA Funding Approval
1996/11/12			Harrisburg meeting with NPS staff
1997/04/11		PADEP, BWC	Quality Assurance Work Plan
1998/04/28	PAUEP, BWC	CUS PARED PMC	ME# 358079 contract
1998/06/23	PADEP_ BWC	SRI SRI	Grait it attister request irom CDS to SKI Receipt of revised correction for oversition
1998/07/13	SRI	PADEP RWC	receipt of revised agreenents for execution Revised evented arreamonts
1998/09/08	PADEP, BWC	SRI	Revised ME# 358079 contract
1998/09/18	PADEP, BWC	SRI	Compliance Review
1999/01/13	SRU	SRI	Service Purchase Contract 390091 (requested by SRU)
1999/01/20	SRI	SRU	Service Purchase Contract 390091 (executed by SRI)
1999/02/02	SRU	SRI	Service Purchase Contract 390091 (rejected by SRU)
1999/02/02	SRU	SRI	Service Purchase Contract SPC-0004 (requested by SRU)
1999/02/03	SRI	BAMR	partnering with BAMR for aerial topo survey
1999/02/03	SRI	SRU	Service Purchase Contract SPC-0004 (executed by SRI)
1999/02/23	SRU	SRI	Service Purchase Contract SPC-0004 (approved by SRU)
1999/03/10	SRI	Knox DMO	mtg w/Bowman regarding BAMR aerial
1999/03/23	SRI	Knox DMO	mtg w/Bowman regarding BAMR aerial
1999/03/24	Knox DMO	BAMR	location of proposed topo survey
1999/05/17	BAMR	SRI	field survey, digital mapping complete
1999/06/08	EADS Group	BAMR	aerial topography complete (OSM PA(map-96) 101.3
1999/07/08	BAMR	SRI	aerial topo mapping
1999/09/08	PADEP, BWC	SRI	Extension - Amendment No. 1 (rec'd 12/23/99)
1999/12/08	SRU	SRI	Amendment 1 extension to SPC-004 (requested by SRU)
1999/12/10	SRI	SRU	Amendment 1 extension to SPC-004 (executed by SRI)
1999/12/14	SRU	SRI	Amendment 1 extension to SPC-004 (approved by SRU)
2000/01/07	SRI	PADEP, BWC	Project Update
2000/01/10	SRI	SRU	Amendment 1 to SPC-004 (executed by SRI)
2000/01/18	SRU	SRI	invoice #791242 (\$4,250) stream assessment (SRI ck1136)
2000/03/31	SRI		field mtg w/R.&Ed Vogel, Youchak, Hockenberry, Gillen
2000/04/18	Youchak	SRI	partnering with Seneca Landfill, Inc. for construction services
2000/04/18	Youchak	Knox DMO	SR89 construction services/Stream Mitigation Plan for Seneca
2000/04/18	Vogel/Seneca Landfill	SRI	Letter of Understanding (executed by SRI 04/25/00)
2000/05/01	PA Game Comm.	SRI	Project approval
2000/06/14	Knox DMO	Vogel/Seneca Landfill	review letter for Seneca Landfill construction services
2000/06/28	BMI	Youchak	preliminary draft design and narrative for passive system
2000/07/14	Youchak	Knox DMO	revisions to SR89 construction services for stream mitigation
2000/08/10	Knox DMO	Vogel/Seneca Landfill	review letter for Seneca Landfill construction services
2000/10/15	Aquascape	SRI	invoice 101500-004 (\$130) EA, PNDI, PHMC
2000/10/25	BMI	McKay&Gould	install piezometers take WL readings
2000/10/25	PA Bureau of Forestry	Aquascape	PA Natural Diversity Inventory - negative determination 010105

2000/10	Aquascape	PHMC	Notification
2000/10/20	BMI	McKay&Gould	install piezometers ke WL readings
2000/10/30	USDOI, FWS	Aquascape	Threaten/Endangered Species - possible massasauga rattlesnake
2000/10/31	PADEP, BWC	SRI -	Extension - Amendment No. 2 (rec'd 01/11/01)
2000/10/31	Aquascape	SRI	invoice 103100-014 (\$207.50) EA, PNDI, PHMC
2000/10/31	Aquascape	SRI	invoice 103100-014A (\$225) EA, PNDI, PHMC
2000/11/02	SRI	Youchak	request for BH location survey tied-in to BAMR stations
2000/11/06	BMI		WL readings at piezometers
2000/11/08	BMI	Vogel/Seneca Landfill	forward McKay&Gould drilling invoice 52673 for payment
2000/11/15	Aquascape	SRI	invoice 111500-004 (\$112.50) EA, PNDI, PHMC
2000/11/20	BMI		piezometers: sample & WL readings
2000/11/30	G&C	BMI	Invoice 40642 (\$297) water sample analyses
2000/11/30	Aquascape	SRI	invoice 113000-003 (\$157.50) EA, PNDI, PHMC
2000/11/30	SRI	PADEP, BWC	Project Update
2001/01/05	PA Game Comm.	Aquascape	PA Natural Diversity Inventory - negative determination
2001/01/11	BMI		piezometers: sample & WL readings
2001/01/31	G&C	BMI	Invoice 40874 (\$539) water sample analyses
2001/01/31	Aquascape	SRI	invoice 013101-003 (\$45) EA, PNDI, PHMC
2001/02/05	BMI		piezometers: sample & WL readings
2001/03/01	PA Fish Comm.	Aquascape	Secondary Species Impact Review - negative determination 5486
2001/03/15	Aquascape	SRI	invoice 031501-003 (\$33.75) EA, PNDI, PHMC
2001/03/31	Aquascape	SRI	invoice 0313101-003 (\$278.75) EA, PNDI, PHMC
2001/04/12	G&C	BMI	Invoice 41305 (\$70.50) water sample analyses
2001/04/15	Aquascape	BMI	invoice 041501-003 (\$1,461.25) EA, PNDI, PHMC
2001/04/19	BMI	PA One Call	underground utilities 1071633
2001/04/19	SRU	SRI	Invoice 790934 (\$4,250) stream assessment (SRI ck2200)
2001/04/23	Aquascape	Washington Twp.	Restoration Waiver Notification
2001/04/23	Aquascape	Butler Co. Comm.	Restoration Waiver Notification
2001/04/24	BMI		piezometers: sample & WL readings
2001/04/30	G&C	BMI	Invoice 41445 (\$539) water sample analyses
2001/04/30	Aquascape	SRI	invoice 043001-006 (\$326.25) EA, PNDI, PHMC
2001/05/08	Aquascape	PADEP, NW Region	Environmental Assessment - Restoration Waiver Request
2001/05/15	Aquascape	SRI	invoice 051501-004 (\$33.75) EA, PNDI, PHMC
2001/06/20	G&C	BMI	Invoice 41609 (\$154) water sample analyses
2001/06/26	PADEP, NW Region	Aquascape	PADEP Waiver of Permit Requirements EA10-016NW
2001/07/10	SRI	PADEP, BWC	Email Update
2001/07/20	PADEP, BWC	SRI	Extension - Amendment No. 3 (rec'd. ~09/24/01)
2001/07/30	SRI	PADEP, BWC	Project Update
2001/09/01	SRI	WPWPP	Funding request to develop wetlands wildlife habitat
2001/10/10	SRI	PADEP, BWC	Project Update
2001/10/23	SRI	PADEP, BWC	Email Update
2001/10/29	BMI	SRI	Invoice #210(\$475.00) Youchak&Youchak ext. request; Amend.#2
2001/10/31	SRI	PADEP, BWC	Invoice 61(\$20,190.57)
2001/11/08	SRI	PADEP, BWC	Report and Reimbursement Request
2001/11/16	PADEP, BWC	SRI	1/8/00 thru 10/29/01 \$20190.57

SRI	SRI	Citizens Bank	PennDot
2001/12/	2001/12)	2001/12/20	2001/12/26

Quality Aggregatesorder limestone acjate (AASHTO #1, 57, R4)Interstate Pipeorder pipe, fittings, ...s10,000 cashier's check for road bondSRITemporary Road Bond 100075 (SRI ck2100; \$258.50)



View "Kill Zone" located below SR89 Discharge. Note the devastating impacts the iron- and aluminum-bearing acidic drainage has had on surrounding vegetation.



(I-r) Dale Hockenberry, PA Game Comm., Margaret Dunn, SRI, Dean Baker, PA DEP, BAMR, Roger Bowman, PA DEP, Knox DMO, and a PA DEP BAMR operator inspect the wetland construction area to evaluate utilizing spent treatment media from the Ferris Complex Treatment System as wetland substrate at the SR89 site.



A drilling program was implemented in order to assess ground water conditions.



Piezometers and monitoring wells were installed in order to evaluate the hydrogeology of the site due the difficult construction conditions. (10/00)



The existing access road was upgraded in order to facilitate materials delivery.



A coordinated effort was needed to receive and stockpile all the materials needed to construct the passive treatment system.

Slippery Rock Creek Headwaters Project Butler County, PA



Bob Beran, Aquascape, conducting the Environmental Assessment of the site.



Soil profile at Observation Point P1 during the Environmental Assessment.



A berm that had previously been built by Slippery Rock Watershed Coalition volunteers to divert flows from the Big Bertha discharge.



Partially wooded wetland area showing silt fence from past attempts to control the excess deposition.



Excessive metal precipitation from discharge SR89.

SLIPPERY ROCK CREEK TARGET AREA



SR89 SITE EVALUATION

Extensive mining on the Brookville coalbed (Clarion Fm.; Allegheny Gp.) by both surface and underground methods has been conducted at the site of the SR89 discharge. The commercial underground mining was completed in the early 1900s. A coal preparation plant (Amos Tipple) was also operated at this site. In the early 1980s under SMP#10820201, coal refuse was backfilled into an abandoned open cut. (See Reference List.) The SR89 discharge is thought to be linked to coal refuse placement at this site.

In addition to SR89, there is a flowing abandoned oil and gas well, known as Big Bertha, which discharges highly degraded water. Since 1970, restoration efforts have been conducted to abate this discharge. Including casing the Big Bertha Well to 72 feet to exclude the degradation from the upper water-bearing zones and building an Anoxic Limestone Drain, placed online in 1996, to treat the remaining flow from the well. Further extensive studies have also been conducted. (See Reference List.)

In addition to backfilling the open Brookville cut and revegetating the site, ACV Power in the mid-1990s inventoried the buried coal refuse in an attempt to utilize the material as fuel for the circulating, fluidized bed Scrubgrass Generating Plant in Kennerdell, PA. Use of the coal refuse was not feasible and degraded drainage associated with this material (SR89) continued to pollute the streams.

Working with the PADEP Knox DMO in a public-private partnership effort, FY98 EPA 319 funding was requested for stream monitoring by Slippery Rock University and Grove City College and for implementation of a passive system to treat SR89. A conceptually sound plan was developed based on the Knox DMO SR89 monitoring data.

As this site had a limited construction area and as further inspection indicated that the elevation of the discharge varied seasonally, additional site data was required. PADEP Bureau of Abandoned Mine Reclamation joined the partnership effort by providing a topographic survey from aerial photography. Working with the PA Fish and Boat Commission and the Knox DMO, Seneca Landfill, Inc. joined the effort by providing drilling services for the installation of 13 piezometers and the more extensive earthmoving required to build the proposed passive system.

Piezometer Data Evaluation

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Thirteen piezometers and two open bores were used to aid in the evaluation of the subsurface flow regime. (See attached logs.) Of the thirteen piezometers, four (30-01B, -02A, -03A, -09) were completed to clay material below the Brookville coalbed horizon and eight (30-01A, -02, -03, -05, -06, -07, -08, -11) were completed in a sandstone or correlative unit below the clay material.

Water-Bearing Zones: Range in Characteristics

Piezo. #	SWE (ft.)	pH (lab)	alkalinity (mg/l)	acidity (mg/l)	Fe (diss.) (mg/l)	Al (diss.) (mg/l)	sulfates (mg/l)
30-01B	1235.6 - 1241.0	2.9 - 3.3	0	250 - 530	5 - 42	8 - 46	600 - 1000
30-02A	1234.0 - 1239.1	3.1 - 3.2	0	190 - 360	18 - 55	24 - 36	400 - 900
30-03A	1231.8 - 1236.6	3.5 - 4.2	0	40 - 140	3 - 10	6 - 14	400 - 500
30-09	1227.5 - 1228.2	3.2 - 4.0	0	160 - 200	9 - 45	8 - 32	500 - 600

Upper: above clay material underlying or near Brookville coalbed horizon

Lower: in sandstone or correlative horizon below Brookville coalbed horizon

Piezo. #	SWE (ft.)	pH (lab)	alkalinity (mg/l)	acidity (mg/l)	Fe (diss.) (mg/l)	Al (diss.) (mg/l)	sulfates (mg/l)
30-01A	1230.7 - 1233.3	3.4 - 4.8	0 - 3	50 - 150	15 - 34	1 - 2	700 - 800
30-02	1230.6 - 1231.0	3.4 - 3.6	0	140 - 190	9 - 12	8 - 12	500 - 700
30-03	1231.8 - 1236.6	3.1 - 3.4	0	140 - 250	5 - 55	11 - 24	400 - 600
30-05	1229.8 - 1230.1	5.4 - 5.8	20 - 26	0	<1 - 2	~1	400
30-06	1230.6 - 1233 <i>.</i> 2	5.5 - 6.0	5 - 16	20 - 90	8 - 26	~1	500 - 600
30-07	1229.2 - 1231.7	3.7 - 4.0	0	290 - 380	100 - 149	10 - 16	900 - 1200
30-08	1229.9 - 1232.2	4.0 - 4.4	0	110 - 130	39 - 212	3 - 4	500 - 600
30-11	1228.4 - 1229.7	3.6 - 3.9	0	100 - 160	10 - 80	5 - 13	500

Static Water Levels

The static water level in the upper zones had a seasonal fluctuation of about 5 feet in all piezometers, except for 30-09 with <1 foot of fluctuation due to the location near a seep (discharge zone) below spoil. During the "dry" and "wet" seasons, the potentiometric surface varied 8 feet to 13 feet, respectively, across the site. The lowest observed elevation is below the coal crop and spoil mound (30-09) with the highest near the backfilled and upland areas (30-01B) on the western portion of the project site. The upper zones are unconfined.

The lower zones demonstrated less seasonal fluctuation from 1 to 3 feet, except for 30-03A which varied about 5 feet. Comparison of the static water levels of the lower and upper zones indicates that the lower zones are confined, at least seasonally and locally, with the potentiometric surface extending above the base of the confining bed. Borehole 30-10 was drilled just downgradient of 30-11 and was a flowing well. The upwelling around a utility pole further indicates this confined condition. The drainage ditch along the railroad grade that borders the construction area may receive drainage from the lower zone as base flow in addition to drainage from the upper zone. Slippery Rock Creek Headwaters Project Butler County, PA

12/2001 103001

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The water quality of the upper zones was variable locally and seasonally. The combined range being from 2.9 to 4.2 pH, no alkalinity, 40 to 530 mg/l acidity, 3 to 55 mg/l dissolved iron, 6 to 46 mg/l dissolved aluminum, and 400 to 1000 mg/l sulfates. The water quality of the lower zones was extremely variable within the project area, ranging from 3.1 to 6.2 pH, 0 to 26 mg/l alkalinity, 0 to 380 mg/l acidity, <1 to 212 mg/l dissolved iron, <1 to 24 mg/l dissolved aluminum, and 400 to 1200 mg/l sulfates. The water quality of the lower zones was of substantially better quality in the northeasterly portion of the project area with the southwesterly portion of the project area exhibiting severely degraded water. The severe degradation is thought to be due to the weathering of buried coal refuse.

The decision was made to remove the spoil mound and construct the Vertical Flow Pond on the clay material that is present below the Brookville coalbed. Subsurface flow above this clay material will be encountered by the Vertical Flow Pond with the breastwork pooling the water within the limestone aggregate. The elevation of the outlet pipes will control the ponded water elevation.

As the railroad ditch appears to encounter some drainage from the lower zone, this water will not be encountered by the Vertical Flow Pond. (VFP bottom ~1229'; railroad ditch ~1225') This flow will be directed, as feasible, into the constructed wetland. Flow from the permanent diversion ditch and upgradient of the construction area will be piped to the westerly side of the railroad grade.

In summary, the upper water-bearing zones will be encountered and treated by the Vertical Flow Pond. The effluent from the Vertical Flow Pond is expected to be net alkaline with no dissolved aluminum. The excess alkalinity is also expected to be sufficient to neutralize the acidity generated by the formation of iron solids. Seepage from the lower water-bearing zones will mix with the Vertical Flow Pond effluent in the constructed wetlands and is expected to substantially improve the combined drainage from the site.

REFERENCE LIST

- Gwin Engineers, Inc., 1970, Slippery Rock Creek Mine Drainage Pollution Abatement Project - Operation Scarlift SL-110: PA Department of Mines and Mineral Industries.
- Thompson, D. R., 1972, Complex Groundwater and Mine Drainage Problems form a Bituminous Coal Mine in Western Pennsyslvania: Association of Engineering Geologists, Bulletin Vol. IX, No. 4. [not available for review]
- Gwin, Dobson & Foreman, Inc., 1984, Hydrogeologic Assessment of Surface Water, Groundwater, and Flowing Artesian Systems on Slippery Rock Creek Watershed, State Game Lands 95, SL 110-7-101.5: PA Department of Environmental Resources, Office of Resources Management, Division of Mine Hazards.
- Bowman, Roger, Project Officer, 1998, Slippery Rock Creek Watershed Comprehensive Mine Reclamation Strategy - Reclamation/Remediation Plan: PA Department of Environmental Protection, Knox Office, District Mining Operations.
- Bowman, Roger, Project Officer, 2001, Slippery Rock Creek Watershed: PA Department of Environmental Protection, Knox Office, District Mining Operations.
- Barnside, Bennett & Niece, Engineers, 1916, Standard Coal Mining Co. Hamilton Mine Scale: 1" = 100' (portion)

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103001

Hole No.:				30-01	Operation Name:	SR89
'9FACE	ELEVATION	N		1245.6	Method of Drilling:	Air-Rotary
O MO	OF COAL EL	EVATIONS	S:	1234.6	Date Drilled:	10/25/00
					_ Drilled By:	McKay&Gould Drilling Co., Darlington, PA
			1235.3 (10/25	5/00) 1235.8 (01/11/01) Logged By:	McKay&Gould Drilling Co., Darlington, PA
Groundwate	er Elevation:	s	1235.2 (10/30	0/00) 1236.3 (02/05/01) Township:	Washington Twp.
and Date M	leasured		1235.3 (11/06	5/00) 1240.9 (04/24/01	County:	Butler
			1235.3 (11/20)/00)	Quadrangle:	
Surveyed b	v:	Earthtech	. Inc.		Laboratory:	<u> </u>
Survey Met	hod:	EDM topo	araphic surve	ev	UTM's Zone:	17 Northing Easting
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	Thisk		Craphia	Lithologic		
Depth	THICK-	Scale	Graphic	Description and		Comments
	ness		Log	Water Conditions		
	5		X~0X	spoil; nd-bn & md-gy, dry		
			X~0X	sh, cs, coal chips		
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				SWL (04/24/01)		
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			~~~~~~			
			~~~~~~	@18 cs; OD (1)		
19	6			sh; md-to dk-gy, dry		
		_ 20 _		@19 sh; carb (1/2)		
25		- ₂₅ -		@24 1/2 sh; carb		
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Page 1 of 1

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7.1(B) GEOLOGIC LOG DRILL HOLES/OVERBURDEN ANALYSIS DATA	

Hole No.:		30-0	1A
TRACE ELE	VATION		1245.6
OM OF C	OAL ELEVATIONS	:1234	.6
		1231.1 (10/30/00)	1231.0 (02/05/01)
Groundwater Ele	evations	1230.9 (11/06/00)	1233.3 (04/24/01)
and Date Measu	red	1230.7 (11/20/00)	
		1230.7 (01/11/01)	
Surveyed by:	Earthtech,	, Inc.	
Survey Method:	EDM top	ographic survey	· · · · · · · · · · · · · · · · · · ·
Remarks:	all dimensions i	n feet	

Operation Name:	SR89
Method of Drilling:	Air-Rotary
Date Drilled:	10/25/00
Drilled By:	McKay&Gould Drilling Co., Darlington, PA
Logged By:	McKay&Gould Drilling Co., Darlington, PA
Township:	Washington Twp.
County:	Butter
Quadrangle:	
Laboratory:	
UTM's Zone:	Northing Easting
LATITUDE	LONGITUDE

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Depth	Thick- ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
	5		X~oX	Spoil, dry	Piezometer
			X~oX		
			X~oX	SH, CS, coal chips	Screen: 20 -slot: Length 5' ' end can 0.8'
			X~oX		
5			X~oX		Biser: 2" Sch. 40 PVC
	6			Coal with binders, dry	
				@71/2 coal (2)	Sand: 430 size; 25 1/2' to 19'
			~~~~	@91/2 cs; ??•gg, parting (1/2)	Bentonite: 19' to surface
(, ,					
	2 1/2		~~~~	cs; lb-to md-gy	Stick-Up: 4
			~~~~		Well Diamator: 4 3/4"
131/2			~~~~~	@ 131/2 damp	
	5 1/2		~~~~~	SH & CS; md-gy	
			~~~~~	@ 15 add rod; < 1/2 gpm	
			~~~~		
			~~~~~		
			~~~~~	@18 CS; OD (1)	
19		_ 20 _	~~~~~		
	6		=======	SH; md to dk-gy, dry	
				@19SH; carb (1/2)	
			• • • • •		
25			=======	@ 241/2 SH; carb	

103001

103001

Hole No.:				30-01B	Operation Name:	SR89
ACE	ELEVATIO	N	-	1245.5	Method of Drilling:	Air-Kotary
	OF COAL EL	EVATION:	S:	1234.5	Date Drilled:	10/25/00
					Drilled By:	McKay&Gould Drilling Co., Darlington, PA
			1235.7 (10/25	5/00) 1236.1 (01/11/01)	Logged By:	McKay&Gould Drilling Co., Darlington, PA
Groundwate	er Elevation	S	1235.7 (10/30	)/00) 1236.7 (02/05/01)	Township:	Washington Twp.
and Date M	leasured		1235.6 (11/06	5/00) 1241.0 (04/24/01)	County:	Buller
			1235.7 (11/20	)/00)	Quadrangle:	
Surveyed b	y:	Earthtech	n, Inc.		Laboratory:	
Survey Met	hod:	EDM top	pographic su	irvey	UTM's Zone:	Northing Easting
Remarks:	ail di	mensions	in feet		LATITUDE	
			1	Lithologia		
Depth	Thick- ness	Scale	Graphic Log	Description and Water Conditions		Comments
			Y= oX	Socili me ha & me au day		
	3		A0A	opon, moron or morgy, dry		Piezometer
			X~oX	SH, CS, coal chips		
			X~oX			and son 0 Cl
			X~oX		Screen: 20 -slot; Length 5';	end cap 0.6
F			Y- aY			
			~		Riser: 2" Sch. 40 PVC	
	6			coal with binders, dry		
						4 /01
				@71/2 coal (2)	Sand: 430 size; 10 1/2" to 4	1/2'
			and an and a second		Bentonite: 4 1/2' to surface	9
		- ¹⁰ -	~~~~~	@91/2 CS parting (1/2)		
1						
			~~~~~	cs; lb-av, dry	Stick-Up: 4.4	
			-		Well Diameter: 4 3/4"	
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Page 1 of 1 103001

7.1(B) GEOLOGIC LOG DRILL HOLES/OVERBURDEN ANALYSIS DATA

Hole No.:	30-02	2	Operation Name:	SR89	
TACE ELEVATION		1252.4	Method of Drilling:	Air-Rotary	
OM OF COAL ELEVATION	S:	1234.9	Date Drilled:	10/25/00	
			Drilled By:	McKay&Gould Drilling Co., Darlington, PA	
	1231.0 (10/30/00)	1231.0 (02/05/01)	Logged By:	McKay&Gould Drilling Co., Darlington, PA	
Groundwater Elevations	1230.8 (11/06/00)	1233.4 (04/24/01)	Township:	Washington Twp.	
and Date Measured	1230.6 (11/20/00)		County:	Butler	
	1230.7 (01/11/01)		Quadrangle:		
Surveyed by: Earthtech	ı, Inc.		Laboratory:		
Survey Method: EDM top	ographic survey		UTM's Zone:	17 Northing Easting	
Remarks: all dimensions	in feet		LATITUDE		

Depth	Thick- ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
	17 1/2	5 5 5 10 10 	XOX X	spoit; tan to org clayey to 5 ¼, dry @5 1/2 stsh; Ib-to md-gy (2 1/2) @8 cs; brn (2) @10 coal bony, cs (7 1/2) sl. damp	Piezometer Screen: 20 -slot; Length 2' ; Riser: 2" Sch. 40 PVC Sand: 430 size; 35 1/2' to 32' Bentonite: 32' to surface Stick-Up: 1.4 Well Diameter: 4 3/4"
17 1/2	2 1/2			cs; lb-gy [bottom], dry	
20	5 1/2	20	~~~~~	SWL (04/24/01) ss; lb-gy, fn-gn SWL (11/20/00) @23 to 24 waler - 3gpm	
	10	30		stsh; md-to dk-gy muddy to dry	
35 1/2					

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Page 1 of 1

103001

Hole No.:		30-0	2A
ACE ELE	VATION		1252.5
OM OF C	OAL ELEVATIONS	: <u>1234</u>	.0
		1234.1 (10/30/00)	1235.4 (02/05/01)
Groundwater Ele	evations	1234.0 (11/06/00)	1239.7 (04/24/01)
and Date Measu	ired	1234.0 (11/20/00)	
		1234.4 (01/11/01)	
Surveyed by:	Earthtech,	, Inc.	
Survey Method:	EDM top	ographic survey	
Remarks:	all dimensions i	n feet	

Operation Name:	SR89
Method of Drilling:	Air-Rotary
Date Drilled:	10/25/00
Drilled By:	McKay&Gould Drilling Co., Darlington, PA
Logged By:	McKay&Gould Drilling Co., Darlington, PA
Township:	Washington Twp.
County:	Butler
Quadrangle:	
Laboratory:	
UTM's Zone:	Northing Easting
LATITUDE	LONGITUDE

Depth	Thick- ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
18 1/2	18 1/2			spoil, lan to org @6 coal (1/2) STSH & CS; brn & md-gy SWL (04/24/01) @4 1/2 binders & coal (3) SWL (11/20/00) CS; ib-gy, dry	Piezometer Screen: 20 -slot; Length 1.9' ; Riser: 2" Sch. 40 PVC Sand: 430 size; 19' to 16' Bentonite: 16' to surface Stick-Up: 3.7 Well Diameter: 4 3/4"

7.1(B) GEOLOGIC LOG DRILL HOLES/OVERBURDEN ANALYSIS DATA

Hole No.:	lo.: <u>30-03</u>					
TITE ACE ELEVATION		1239.1	Metho			
OM OF COAL ELEV	ATIONS:	1228.6	Date D			
			Drilled			
	1230.1 (10/25/00)	1230.4 (01/11/01)	Logge			
Groundwater Elevations	1230.4 (10/30/00)	1230.8 (02/05/01)	Towns			
and Date Measured	1230.3 (11/06/00)	1235.2 (04/24/01)	County			
	1230.1 (11/20/00)		Quadra			
Surveyed by: Ea	arthtech, Inc.		Labora			
Survey Method: El	DM topographic survey		UTM's			
Remarks: all dime	nsions in feet		LATIT			

ation Name:	SR89
d of Drilling:	Air-Rotary
Drilled:	10/25/00
d By:	McKay&Gould Drilling Co., Darlington, PA
ed By:	McKay&Gould Drilling Co., Darlington, PA
ship:	Washington Twp.
y:	Butler
rangle:	
atory:	
s Zone:	Northing Easting
UDE	LONGITUDE

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Depth	Thick- ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
ſ	7		~~~~~	cs; bright org., v. wx, damp	Piezometer
			~~~~~	@1/2 cs; carb (1/2)	
			~~~~~~		Screen: 20 -slot: Length 2 1' :
			~~~~~~	SWL (04/24/01)	
			::::::~ ~ ~ ~ ~	some ss; bright org. fn-gn, damp	Riser: 2" Sch. 40 PVC
			~~~ ;;;;;;;;		
7			~~~~~~		Sand: 430 size: 14' to 11'
	2			ss; bright org., v. wx	
9			******	SWL (11/20/00)	Bentonite: 15' to 14': 11' to surface
	1 1/2	_ 10 _		coal , v. wx, clayey, damp	
					Stick-Up: 2.7'
10 1/2					
	3 1/2		:~:~:~:	ss & cs; bright org	Well Diameter: 4 3/4"
	2 - -		:~:~:~:	@ 11 1/2 water	
				@ 12 ss; org., nd-gn(2), water	
14	ļ				
15	1		~~~~~~	cs; bright org., water	
		_ 20 _			
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		30			
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Hole No.:	30-03	3A	Operation Name:	SR89
THIS FACE ELEVATION	۹	1239.6	Method of Drilling:	Air-Rotary
OM OF COAL EL	EVATIONS:	1229.1	Date Drilled:	10/25/00
			Orilled By:	McKay&Gould Drilling Co., Darlington, PA
	1232.4 (10/30/00)	1233.5 (02/05/01)	Logged By:	McKay&Gould Drilling Co., Darlington, PA
Groundwater Elevations	s <u>1232.0 (11/06/00)</u>	1236.6 (04/24/01)	Township:	Washington Twp.
and Date Measured	1231.8 (11/20/00)		County:	Buller
	1232.7 (01/11/01)		Quadrangle:	
Surveyed by:	Earthtech, Inc.		Laboratory:	
Survey Method:	EDM topographic survey		UTM's Zone:	Northing Easting
Remarks: all din	nensions in feet		LATITUDE	

Depth	Thick- ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
	7		~~~~~~	cs; bright org, v. wx, damp @ 1/2 cs; carb (1/2)	Piezometer
			~~~~~~	SWL (04/24/01)	Screen: 20 -slot; Length 2' ;
			~ ~ ~ ~ ~ ~	some ss; bright org.	Riser: 2" Sch. 40 PVC
7	2			fn-gn, damp ss; bright org., v. wx	Sand: 430 size; 10 1/2' to 7'
9	1 1/2			SWL (11/20/00) coal; v. wx, clayey, damp	Bentonite: 7' to surface
					Stick-Up: 2.2'
					Well Diameter: 4 3/4"
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Page 1 of

103001

Hole No.:	30-	04	Operation Name:	SR89		
ACE ELEVATI	ON		Method of Drilling:	Air-Rotary		
OM OF COAL	ELEVATIONS:		Date Drilled:	10/25/00		
	-		Drilled By:	McKay&Gould Drilling Co., Darlington, PA		
			Logged By:	McKay&Gould Drilling Co., Darlington, PA		
Groundwater Elevation	ons		Township:	Washington Twp.		
and Date Measured			County:	Butler		
			Quadrangle:			
Surveyed by:	Earthtech, Inc.		Laboratory:			
Survey Method:	EDM topographic surve	У	UTM's Zone:	Northing Easting		
Remarks: all	dimensions in feet		LATITUDE			

Depth	Thick- ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
1	1		///////////////////////////////////////	regolith; nd-bn	
	34		X~oX	spoil; md-gy & ord.	
				@ 1 sh & cs; md-gy, v wx (6)	
				st. damp	
			~~~~~~		
				@7 sh; OD (1) sl. damp	
			:~:~:~:	@8 ss; org, v, wx	
		_ 10	:~:~:~:	with cs; nd-gy damp	
			:~:~:~:		
			:~:~:~:		
			:~:~:~:		
			~~!:~~	@13 cs; md-gy some ss (5 1/2)	
			~~::~~		
			~~::~~		
			~~::~~		
			~~::~~		
			XXXXXXX	@18 1/2 "red dog" (5 1/2)	
		- ²⁰ -	XXXXXXX	with some coal, cs, sh	
			XXXXXXX		
			~:~:~:~		
			~:~:~:~		
			XXXXXXXX		
				@25 poor return	
				·	
		_ ³⁰ _			
35				(hole collapsing)	····
				STS; md-gy	
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7.1(B) GEOLOGIC LOG DRILL HOLES/OVERBURDEN ANALYSIS DATA

Hole No.:	30-05	Operation Name:	SR89
CURFACE ELEVATION	1232.3	Method of Drilling:	Air-Rotary
OM OF COAL ELEVAT	IONS:	Date Drilled:	10/30/00
		Drilled By:	McKay&Gould Drilling Co., Darlington, PA
	1230.1 (10/30/00) 1230.1 (02/05/01)	Logged By:	McKay&Gould Drilling Co., Darlington, PA
Groundwater Elevations	1229.9 (11/06/00) 1233.2 (04/25/01)	Township:	Washington Twp.
and Date Measured	1229.8 (11/20/00)	County:	Butler
	1229.8 (01/11/01)	Quadrangle:	
Surveyed by: Earth	itech, Inc.	Laboratory:	
Survey Method: EDM	1 topographic survey	UTM's Zone:	NorthingEasting
Remarks: all dimension	ons in feet	LATITUDE	LONGITUDE

Remarks:	all di	mensions i	in feet		_ LATITUDE	
Depth	Thick- ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Co	omments
	1 1/2		X~oX	spoil; md-bn, with		· · · · · · · · · · · · · · · · · · ·
1/2			X~oX	carb SH frogs, damp	<u><u>Pie</u></u>	zometer
	9		~~~~~	cs; md-org, v. wx	Carrows 20. alatt Langth 0.4/01.	
			~~~~~~	@3 cs, gry & org motiles	Screen: 20 -slot; Length 2 1/2';	
					Diago Ol Cab. (0 D)(0	
				(wet, damp, and dry zones)	Riser 2 Sch. 40 PVC	
			~~~~~~		Cand: 420 alars: 451 to 44 4/01	
			~~~~~~	SWL (04/24/01)	Sand: 430 size; 15° to 11 1/2°	
				@8 coal chips	Deptemites 11 1/21 to evidence	
		_ 10 _			Bentonite: 11 1/2 to surface	
			~~~~~~	SWL (11/20/00)	Stick Lip: 17	
	3		~.~.~.~	MS & SH; md-gy & OP		
				@12 1/2 org stks	Wall Diamator: 4.2/4"	
31/2				@13 1/2 water - 3 gpm		
	1 1/2			ss; dk-gy, bn-gn		
				med hard, water		
15						
		_ 20 _				
		- ³⁰ -				

103001

7.1(B) GEOLOGIC LOG DRILL HOLES/OVERBURDEN ANALYSIS DATA

Hole No.:		30-00	6
ACE ELE	VATION		1240.3
OM OF C	OAL ELEVATI	ONS:	
		1230.8 (10/30/00)	1230.9 (02/05/01)
Groundwater Ele	evations	1230.6 (11/06/00)	1233.2 (04/24/01)
and Date Measu	ıred	1230.6 (11/20/01)	
		1230.6 (01/11/01)	
Surveyed by:	Earth	ech, Inc.	
Survey Method:	EDM	topographic survey	
Remarks:	all dimensio	ons in feet	

Operation Name:
Method of Drilling:
Date Drilled:
Drilled By:
Logged By:
Township:
County:
Quadrangle:
Laboratory:
UTM's Zone:
LATITUDE

Air-Rotary		
10/30/00	1	
10/30/00	vid Drilling Co	Dealling DA
искауа Go	ula Dhiling Co.,	Danington, PA
<pre>////////////////////////////////////</pre>	uld Drilling Co.,	Darlington, PA
Nashingtor	і Тур.	
Butler		
	Northing	Easting

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Depth	Thick- ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
	2		X~oX	spoil; SH; md-gy;	Piezometer
2			X~oX	bony; ss frags, dry	<u>- 1620116161</u>
3	1		<u>~.~.~.</u> ~	ms & stsh; bik, dry	Screen: 20 -slot: Length 1.8' :
	3			sts ; tan, org, and	
				md- to db-gy	Riser: 2" Sch. 40 PVC
6					
	4 1/2		~~~~~~	cs; lb-lo med bm, dry	Sand: 430 size: 23' to 18'
				SWL (04/24/01)	
			~~~~~~		Rentonite: 25' to 23': 18' to surface
		10 _			
			~~~~~	SWL (11/20/00)	Stick-Up: 4.3'
	4			sh; md to dk-gy, bik, mild	олок-ор. 4.0
			******	carb zones, dry	Well Diameter: 4 3/4"
14 1/2					
	2 1/2			sish; carb, dry	
17			~.~.~.~	@16 ms; carb (1')	
	2			sts nd- to dk-gy, dry	
19			•.•. • .•		
	6	_ 20 _		ss; md- to ak-gy fin-gn	
			••••••		
			••••••	@21 1/2 - 5 gpm	
25					
		_ 30 _			
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103001

Hole No.:	30-07	Operation Name:	SR89
	1229.9	Method of Drilling:	Air-Rotary
OM OF COAL ELEVAT	-IONS:	Date Drilled:	10/30/00
		Drilled By:	McKay&Gould Drilling Co., Darlington, PA
	1229.6 (10/30/00) 1229.6 (02/05/01)	Logged By:	McKay&Gould Drilling Co., Darlington, PA
Groundwater Elevations	1229.5 (11/06/00) 1231.7 (04/24/01)	Township:	Washington Twp.
and Date Measured	1229.3 (11/20/00)	County:	Butler
	1229.2 (01/11/01)	Quadrangle:	
Surveyed by: Earth	ntech, Inc.	Laboratory:	
Survey Method: EDN	/ topographic survey	UTM's Zone:	Northing Easting
Remarks: all dimensi	ons in feet	LATITUDE	

Depth	Thick- ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
	1 1/2		///////////////////////////////////////	sbs; ak-bn, coal chips, damp	Piezometer
1 1/2		<u> </u>	///////////////////////////////////////		
3	1 1/2			ss; gy & bright org, clayey	Screen: 20 -slot; Length 2 1/2'
	4		~~~~	cs; abund. Ib-gy &	
			~~~~	org motlies, damp	Riser: 2" Sch. 40 PVC
			~~~~~		
7			~~~~	@7 water <½ gpm	Sand: 430 size; 15' to 10 1/2'
	4 1/2			ss; org, and cs; lb-gy, wet	Bentonite: 10 1/2' to surface
		_ 10 _	~~~~~		
			••••••		Stick In: 1.8'
11 1/2			~ ~ ~ ~ ~		010k-0p. 1.0
	3 1/2			ss; md-gn, md-gy and pink	Well Diameter: 4 3/4"
				si; hard, wet	
				@13 1/2 water - 5 gpm	
15					
		_ 20 _			
	-	. <u> </u>			
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		_ 30 _			
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Page 1 of 1

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7.1(B) GEOLOGIC LOG DRILL	. HOLES/OVERBURDEN ANALYSIS DATA	

Hole No.:	30-08	Operation Name:	SR89
CONSACE ELEVATION	1232.0	Method of Drilling:	Air-Rotary
OM OF COAL ELEV	VATIONS:	Date Drilled:	10/30/00
	······································	Drilled By:	McKay&Gould Drilling Co., Darlington, PA
	1230.2 (10/30 <u>/00) 1230.2 (02/05/01)</u>	Logged By:	McKay&Gould Drilling Co., Darlington, PA
Groundwater Elevations	1230.1 (11/06/00) 1232.2 (04/24/01)	Township:	Washington Twp.
and Date Measured	1229.9 (11/20/00)	County:	Butler
	1230.0 (01/11/01)	Quadrangle:	
Surveyed by: E	arthtech, Inc.	Laboratory:	
Survey Method: E	DM topographic survey	UTM's Zone:	Northing Easting
Remarks: all dime	nsions in feet	LATITUDE	LONGITUDE

Depth	Thick- ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
2 1/2	2 1/2			SWL (04/24/01) sbs; org & frn; some ib-gy & black, clayey, damp SWL (11/20/00)	Piezometer Screen: 20 -slot; Length 2 1/2'
	3 1/2		~~~~~	cs; lb-gy & org motiles, damp @3 sts; org, v wx (1') @5 cs; md-gy lo bo (1/2')	Riser: 2" Sch. 40 PVC Sand: 430 size; 15' to 11 1/2' Bentonite: 11 1/2' to surface
6		 		@5 1/2 sh; md-gy to bik, cab	Stick-Up: 2.3'
15	9			ss; Ib-to md-gy, damp 9 1/2 cs; Ib-gy (2) @12 1/2 wet @13 1/2 ss; mod hard water - 5 gpm @14 1/2 ss; bik	Well Diameter: 4 3/4"
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103001

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Page 1 of 1

103001

Hole No.:	30-09	Operation Name:	SR89
SUPFACE ELEVATION	۰	1231.7 Method of Drilling:	Air-Rotary
OM OF COAL EL	EVATIONS:	Date Drilled:	10/30/00
		Drilled By:	McKay&Gould Drilling Co., Darlington, PA
	1227.7 (10/30/00) 1227.5	5 (02/05/01) Logged By:	McKay&Gould Drilling Co., Darlington, PA
Groundwater Elevation	s <u>1227.6 (11/06/00)</u> 1228.2	2 (04/24/01) Township:	Washington Twp.
and Date Measured	1227.6 (11/20/00)	County:	Butler
	1227.5 (01/11/01)	Quadrangle:	
Surveyed by:	Earthtech, Inc.	Laboratory:	
Survey Method:	EDM topographic survey	UTM's Zone:	Northing Easting
Remarks: all di	mensions in feet	LATITUDE	LONGITUDE

Depth	Thick- ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
Depth 4 1/2 7 7 1/2	1 hick- ness 4 1/2 2 1/2 1/2	Scale		Description and Water Conditions spoil; damp @1 sh; md-gy & fn (1) @2 cs; tb-to md-gy, brn coal chips, damp SWI. (04/24/01) SWI. (01/11/01) iron (crusty); dk-bn & dk-red twigs & leaves, wet @7 water - 1gpm cs; md-gy	Comments <u>Piezometer</u> Screen: 20 -slot; Length 2 1/2' Riser: 2" Sch. 40 PVC Sand: 430 size; 7 1/2' to 4' Bentonite: 4' to surface Stick-Up: 2.3' Well Diameter: 4 3/4"
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Page 1 of

103001

Hole No.:	30-10	Operation Name:	SR89
SUBFACE ELEVATION		Method of Drilling:	Air-Rotary
OM OF COAL ELEVATIONS:		Date Drilled:	10/30/00
		Drilled By:	McKay&Gould Drilling Co., Darlington, PA
	· · · · ·	Logged By:	McKay&Gould Drilling Co., Darlington, PA
Groundwater Elevations		Township:	Washington Twp.
and Date Measured		County:	Butler
		Quadrangle:	
Surveyed by: Earthtech, Inc.		Laboratory:	
Survey Method: EDM topographic	survey	UTM's Zone:	Northing Easting
Remarks: all dimensions in feet		LATITUDE	

Depth	Thick- ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
	2 1/2		~~~~~	cs; org & cool; wx damp	
2 1/2			~~~~~		
	12 1/2			ss; md-org, md-gn sl, wet	
				@7 1/2 nolgy, clayey (3)	
				10 1/2 water - 7 gpm	
				@12 1/2 ss; v lg chips, rounded	
15		<u> </u>		10/30/00 - flowing well	
		25			

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103001

Hole No.:	30-11	Operation Name:	SR89
CUDEACE ELEVATION	1229.2	Method of Drilling:	Air-Rotary
OM OF COAL ELEVATI	ONS:	Date Drilled:	10/30/00
		Drilled By:	McKay&Gould Drilling Co., Darlington, PA
	1228.7 (10/30/00) 1228.5 (02/05/01)	Logged By:	McKay&Gould Drilling Co., Darlington, PA
Groundwater Elevations	1228.7 (11/06/00) 1229.7 (04/24/01)	Township:	Washington Twp.
and Date Measured	1228.6 (11/20/00)	County:	Butler
	1228.4 (01/11/01)	Quadrangle:	
Surveyed by: Earth	tech, Inc.	Laboratory:	
Survey Method: EDM	topographic survey	UTM's Zone:	Northing Easting
Remarks: all dimension	ons in feet	LATITUDE	LONGITUDE

Depth	Thick- ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
4	1		<u> </u>	SWL (04/24/01) 220[base: sh & ss_damn	Piezometer
2	1			SWL (01/11/01)	Screen: 20 -slot: Length 2 1/2';
	2			ss; org * lb-gy, nd-gn, damp	Riser: 2" Sch. 40 PVC
					Sand: 430 size: 4' to 1/2'
4					Bentonite: 1/2' to surface
		_ °_ 			Stick_lin: 1'
					Well Diameter: 4 3/4"
					Weil Diameter: 4 0/4
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		- 20 -			
		_ 25 _			
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Page 1 of

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103001

Hole No.:	30-12	Operation Name:	SR89
TACE ELEVATION	1220.5	Method of Drilling:	Air-Rotary
OM OF COAL ELEVA	ATIONS:	Date Drilled:	10/30/00
		Drilled By:	McKay&Gould Drilling Co., Darlington, PA
	1215.1 (10/30/00) 1217.9 (04/24/01)	Logged By:	McKay&Gould Drilling Co., Darlington, PA
Groundwater Elevations	1217.7 (11/06/00)	Township:	Washington Twp.
and Date Measured	1217.7 (01/11/01)	County:	Butler
	1217.8 (02/05/01)	Quadrangle:	
Surveyed by:	Earthtech, Inc.	Laboratory:	
Survey Method:	EDM topographic survey	UTM's Zone:	NorthingEasting
Remarks: all dimen	sions in feet	LATITUDE	

Depth	Thick- ness	Scale	Graphic Log	Lithologic Description and Water Candiliana	Comments
	3		X~~0X	spoil: sh: dk-ov & dk-bn dry	
	, i i i i i i i i i i i i i i i i i i i		X~0X		Plezometer
			X~0X		Screen: 20 -slot; Length 5' ; end cap 0.5'
3			X~0X X~0X		Riser: 2" Sch. 40 PVC
	5		~ ~ ~ ~ ~ ~	cs; org some sish; bright red	(hole squeezing unable to place gravel pack)
			~~~~~	v.v. muddy	
			~~~~~		Stick-Up: 2'
			~~~~~		Well Diameter: 4 3/4"
			~~~~~		
8	7		X~oX	spoil, leave, twigs, bron	
			X~oX X~oX		
		10	X~-oX X~-oX	@10.1/2 water 4-5 com	
· ·			X~oX	gre ne nene regent	
			X~0X		
			х~ох Х~оХ		
			X~oX X~oX		
15			X~0X X~0X		
		20			
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Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field PH	PH 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)	(T) Mn (mg/L)	D. Mn (mg/L)	AI (mg/L)	D. AI (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW1	11/20/00			3.6	3.6	1025	8		0	271		7.9		4.6		10.8	632	31
MW1	1/11/01			2.9	3.1	1277	11		0	412	42.4	40.8	4.3	3.9	41.5	37.3	814	11
MW1	4/24/01			3.0	3.1	1069	6		0	249	8.3	8.1	3.4	3.3	25.0	24.1	574	20
	Vin			2.9	3.1	1025	80		0	249	8.3	6.7	3.4	3.3	25.0	10.8	574	-1
ľ	Иах			3.6	3.6	1277	11		0	412	42.4	40.8	4.3	4.6	41.5	37.3	814	31
	Avg			3.2	3.3	1124	0		0	311	25.4	18.9	3.8	4.0	33.3	24.1	673	21
Å.	ange			0.7	0.5	252	3		0	163	34.1	32.9	1.0	1.3	16.5	26.6	240	20
Total Loa	ding (Ib/	(day)																

SR89 Database (103001)

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SR89	Wa	Iter	Ø	Ja		y Da	tab	as	e								1	
Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	da Hq	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 I (mg/L) (0. Mn mg/L)	AI (mg/L)	D. AI (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW1A	11/20/00			5.0	4.6	1345	10			153	76.0		3.3		41.8		676	20
MW1A	1/11/01			4.7	4.8	1145	11		e	117	48.0	33.8	2.2	2.0	3.2	2.4	764	25
MW1A	4/24/01			3.9	3.4	1179	10		0	2	15.8	15.2	2.0	1.9	2.1	1.4	691	21
	Min			3.9	3.4	1145	10		0	54	15.8	15.2	2.0	1.9	2.1	1.4	676	20
	Мах			5.0	4.8	1345	11		3	153	76.0	33.8	3.3	2.0	41.8	2.4	764	25
	Avg			4.5	4.3	1223	10		-	108	46.6	24.5	2.5	2.0	15.7	1.9	711	22
Ř	ange			1.1	1.5	200	L		e	66	60.2	18.6	1.4	0.1	39.7	1.0	88	5
Total Loa	ding (lb/c	day)																

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SR89 Database (103001)

Monday, February 18, 2002

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Page 7 of 22
SR89	Wa	ater	Ø	la l	lit	y Da	Itab	as	0									
Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Ъ Н	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) (r	Mn D Mg/L) (r	. Mn ng/L) (AI Mg/L) (D. AI (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW1B	11/20/00			5.1	3.3	1153				310		20.9		2.6		8.4		692
MW1B	1/11/01			2.8	2.9	1546	6		0	534	54.0	41.9	3.8	3.7	47.8	46.0	1002	280
MW1B	4/24/01			3.0	3.1	1039	8		0	256	6.6	5.0	3.1	3.0	27.1	25.0	554	76
-	Min			2.8	2.9	1039	8		0	256	6.6	5.0	3.1	2.6	27.1	8.4	554	76
4	Мах			5.1	3.3	1546	6		0	534	54.0	41.9	3.8	3.7	47.8	46.0	1002	692
1	Avg			3.6	3.1	1246	6		0	367	30.3	22.6	3.4	3.1	37.4	26.5	778	349
Ŗ	ange			2.3	0.5	507	-		0	278	47.4	36.9	0.7	1.1	20.7	37.6	448	616
Total Loa	ding (lb/	(day)				-									-			

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SR89 Database (103001)

Monday, February 18, 2002

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11/20/00 1/11/01 4/24/01 Min Max	Flow Meas.	(gpm)	Field 1 PH 3.5 3.7 3.7 3.7 3.7 3.7 3.7	PH PH 3.6 PH	Spec. cond. (umhos/cm) 1043 1030 1034 1034 1034	Field Temp (C) 9 9 11	Alk. (F) (mg/L)	Alk. (L) (mg/L) 0 0 0 0	Acid. (mg/L) 136 185 163 136	Fe (mg/L) 10.5 11.5 10.5 11.5 10.5 11.5 11.5 11.5	D. Fe (mg/L) (12.2 8.8 8.8 8.8	Mn (mg/L) 2.0 2.0 4.4	D. Mn (mg/L) 2.3 1.9 1.9	Al (mg/L) 7.5 8.1 8.1	D. Al (mg/L) 12.8 7.3 7.6 7.6 7.8	Sulfate (mg/L) 527 704 527 527 527	Susp. Solids (mg/L) 5 26 43 6 7 3
Avg			3.6	3.5	1056	10		0	161	11.0	10.5	3.2	50	7.8	9.2	590	25
Kange oading (lb/d	ay)		0.2	N 0	2			0	49	- -	34	2.4	0 4	0.6	5.5	178	38

SR89 Database (103001)

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Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	pH 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)	AI (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW2A	1/11/01			3.3	3.2	1355	0		0	358	39.3	31.7	5.2	5.0	37.6	35.8	949	35
MW2A	4/24/01			3.1	3.1	1185	10		0	320	21.1	18.2	4,4	4.4	33.4	32.5	640	100
	Min			3.1	3.1	1185	6		0	320	21.1	18.2	4.4	4.4	33.4	32.5	640	35
	Max			3.3	3.2	1355	10		0	358	39.3	31.7	5.2	5.0	37.6	35.8	949	100
	Avg			3.2	3.2	1270	10		0	339	30.2	25.0	4.8	4.7	35.5	34.1	794	68
Ω.	ange	*		0.2	0.1	170	-		0	38	18.2	13.5	0.8	0.7	4.2	3.3	309	65
Total Loa	lding (lb/	(day)											-	:				

SR89 Database (103001)

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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)
NW3	11/20/00			3.1	3.2	941	თ		0	191		55.5		3.0		24.0	394	18
WW3	1/11/01			3.3	3.4	808	თ		0	141	12.8	11.2	2.0	2.0	11.3	10.7	433	13
VW3	4/24/01			3.0	3.1	1040	σ		0	254	5.1	5.0	2.8	2.8	24.9	22.1	591	4
Z	lin			3.0	3.1	808	σ		0	141	5.1	5.0	2.0	2.0	11.3	10.7	394	4
¥	lax			3.3	3.4	1040	6		0	254	12.8	55.5	2.8	3.0	24.9	24.0	591	18
A	vg			3.1	3.2	930	6		0	195	8.9	23.9	2.4	2.6	18.1	18.9	473	12
Ra	nge			0.3	0.3	232	0		0	113	7.6	50.5	0.7	1.0	13.7	13.3	197	14
Total Load	ling (Ib/	'day)																
			1										-	_	1			

SR89 Database (103001)

Page 11 of 22

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		usp. Solids (mg/L)	7	15	33	7	33	18	26
		sulfate S (mg/L)	369	397	519	369	519	428	150
		D. Al S (mg/L)		6.4	13.9	6.4	13.9	10.2	7.5
		AI (mg/L)	7.4	7.3	17.0	7.3	17.0	10.5	9.7
		D. Mn (mg/L)		5.0	2.5	2.5	5.0	3.8	2.5
		(T/Gm)	6.9	5.2	2.5	2.5	6.9	4.9	4.3
		D. Fe (mg/L)		2.8	9.8	2.8	9.8	6.3	0-7
		Fe (mg/L)	4.2	3.1	10.1	3.1	10.1	5.8	6.9
		Acid. (mg/L)	64	83	140	40	140	88	101
	Ð	AIk. (L) (mg/L)	0	0	0	0	0	0	0
(as	Alk. (F) (mg/L)	-						-
	tab	Field / Temp (C)	.	Ø	5	80	11	6	e
	y Da	Spec. cond. (umhos/cm)	740	692	826	692	826	753	134
	lit	Lab PH	4.2	3.7	3.5	3.5	4.2	3.8	0.7
	la	Field pH	4.1	3.6	3.5	3.5	4.1	3.7	0.6
	ð	Flow (gpm)							
	Iter	Method of Flow Meas.	-						
	Wa	Date	11/20/00	1/11/01	4/24/01	lin	ax	٨g	nge
	SR89	Sample Point	MW3A	MW3A	MW3A	W	M	A	Ra

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Total Loading (Ib/day) Range

SR89 Database (103001)

Monday, February 18, 2002

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Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field PH	Lab PH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	AIk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	AI (mg/L)	D. AI (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
AW5	11/20/00			5.4	6.2	755	σ		26	0	2.5		2.3		2.4		374	22
AW5	1/11/01			5.7	6.2	693	9		26	0	2.0	1.5	2.1	2.1	1.5	0.0	397	23
AW5	4/24/01			5.8	6.2	723	6		20	0	1.3	0.1	2.7	2.7	1.6	0.3	417	11
M	in			5.4	6.2	693	9		20	0	1.3	0.1	2.1	2.1	1.5	0.0	374	41
W	ax			5.8	6.2	755	6		26	0	2.5	1.5	2.7	2.7	2.4	0.3	417	23
A	۶			5.6	6.2	724	8		24	0	1.9	0.8	2.4	2.4	1.8	0.1	396	19
Rai	nge			0.4	0.1	62	3		9	0	1.2	1.4	0.6	0.6	1:0	0.2	43	12
Total Load	/qI) Bui	'day)																

SR89 Database (103001)

Monday, February 18, 2002

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Page 13 of 22

SR89	Me	ater	d	a la		y Da	Itab	as	e									
Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	pH 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)	0. Mn mg/L)	AI (mg/L)	D. AI (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW6	11/20/00			5.5	5.7	1050	11		16	89	25.9		2.7		0.6		609	3
MW6	1/11/01			5.3	6.0	852	10		16	33	13.2	11.6	1.9	1.9	0.3	0.1	516	Ø
MW6	4/24/01			5.3	5.5	869	10		S	18	9.4	8.2	1.9	1.8	0.9	0.2	466	13
	Min			5.3	5.5	852	10		5	18	9.4	8.2	1.9	1.8	0.3	0.1	466	3
	Мах			5.5	6.0	1050	11		16	68	25.9	11.6	2.7	1.9	0.9	0.2	609	13
	Avg			5.4	5.7	924	10		12	47	16.2	9.9	2.1	1.8	0.6	0.2	530	ω
Ä	ange			0.2	0.5	198	1		10	70	16.5	3.4	0.8	0.1	0.5	0.2	143	10
Total Loa	ding (lb/	/day)								ľ								

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SR89 Database (103001)

Monday, February 18, 2002

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Page 14 of 22

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Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	AIK. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L.)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	AI (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
7WM	11/20/00			3.6	3.7	1346	7		0	345	148.5		3.7		16.2		1213	76
7WM	1/11/01	-		3.9	3.7	1333	9		0	378	132.8	129.5	3.7	3.6	15.4	13.6	919	19
MW7	4/24/01			3.9	4.0	1185	10		0	287	103.3	100.0	3.3	3.3	10.6	9.9	875	2
	Min			3.6	3.7	1185	9		0	287	103.3	100.0	3.3	3.3	10.6	9.9	875	2
2	Aax			3.9	4.0	1346	10	8	0	378	148.5	129.5	3.7	3.6	16.2	13.6	1213	76
4	lvg			3.8	3.8	1288	80		0	336	128.2	114.8	3.6	3.4	14.1	11.8	1002	32
Å	ange			0.3	0.3	161	4		0	6	45.3	29.5	0.4	0.4	5.7	3.7	339	74
Total Loa	ling (Ib/	day)											1					
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SR89 Database (103001)

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Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	PH 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)	AI (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)	
MW8	11/20/00			4.6	4.4	767	6		0	106	41.6		6.7		4.6		482	24	
MW8	1/11/01			4.1	4.0	815	5		0	129	40.3	39.0	6.3	6.2	3.7	2.9	519	16	
MW8	4/24/01			4.2	4.0	880	10		0	119	209.0	212.3	7.1	7.1	4.6	3.8	582	19	
V	Min			4.1	4.0	767	5		0	106	40.3	39.0	6.3	6.2	3.7	2.9	482	16	
2	Aax			4.6	4.4	880	10		0	129	209.0	212.3	7.1	7.1	4.6	3.8	582	24	
4	Vg			4.3	4.2	821	8		0	118	96.9	125.6	6.7	6.6	4.3	3.4	528	20	
R	ange			0.5	0.4	113	5		0	23	168.8	173.3	0.8	0.9	0.9	0.8	66	ω	
Total Load	/dl) gnib	day)																	

SR89 Database (103001)

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Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	PH 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 t mg/L) (D. Mn mg/L) (AI (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)	
6MW	11/20/00			4.3	4.0	848	6		0	158	57.5	34.4	4.3	3.2	32.4	8.2	565	144	
6MM	1/11/01			4.3	3.7	837	ø		0	199	52.8	44.8	3.1	3.0	10.0	8.3	536	67	
6MM	4/24/01			4.6	3.9	873	10		0	176	51.5	9.2	3.8	3.6	17.9	11.2	570	37	
	Min			4.3	3.7	837	8		0	158	51.5	9.2	3.1	3.0	10.0	8.2	536	37	
	Max			4.6	4.0	873	10		0	199	57.5	44.8	4.3	3.6	32.4	11.2	570	144	
	Avg			4.4	3.8	853	6		0	178	53.9	29.5	3.8	3.3	20.1	9.2	557	83	
R	ange			0.3	0.3	36	2		0	41	6.0	35.6	1.2	0.6	22.4	3.0	35	107	
Total Loa	dina (Ib/	(dav)			1								-						

SR89 Water Quality Database

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SR89 Database (103001)

Monday, February 18, 2002

Page 17 of 22

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123	100	8.8	3.8	1.7	0.0	70.1	5.2	28	0		9	61	0.3	0.3			ange	Ŗ
48	496	9.8	16.0	4.0	4.9	34.5	15.4	126	0		Ø	811	3.8	3.9			Avg	1
129	546	13.3	17.9	46	4.9	80.0	18.0	159	0		12	834	3.9	4.1			Иах	
9	446	4.5	14.1	2.9	4.9	10.0	12.9	101	0		9	773	3.6	3.8			Min	-
10	546	13.3	17.9	4.4	4.9	13.6	18.0	159	0		12	834	3.6	3.8			4/24/01	MW11
9	495	11.8	14.1	4.6	4.9	10.0	12.9	119	0		9	827	3.8	4.1			1/11/01	MW11
129	446	4.5		2.9		80.0		101	0		7	773	3.9	3.9			11/20/00	MW11
Susp. Solids (mg/L)	Sulfate ((mg/L)	D. AI (mg/L)	AI (mg/L)	D. Mn (mg/L)	(mg/L)	D. Fe (mg/L)	Fe (mg/L)	Acid. (mg/L)	Alk. (L) (mg/L)	Alk. (F) (mg/L)	Field Temp (C)	Spec. cond. (umhos/cm)	pH PH	Field PH	Flow (gpm)	Method of Flow Meas.	Date	Sample Point

SR89 Database (103001)

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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)	(mg/L) (mg/L)	D. Mn (mg/L)	AI (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW12	1/11/01			3.8	3.4	1670	8		0	489	212.8	196.8	7.0	6.6	0.8	0.6	949	32
MW12	4/24/01			4.2	3.6	1506	10		0	369	220.0	194.3	6.4	6.4	0.8	0.3	970	36
V	din			3.8	3.4	1506	80		0	369	212.8	194.3	6.4	6.4	0.8	0.3	949	32
2	1ax			4.2	3.6	1670	10		0	489	220.0	196.8	2.0	6.6	0.8	0.6	970	36
A	VUG			4.0	3.5	1588	6		0	429	216.4	195.5	6.7	6.5	0.8	0.4	959	34
Ra	nge			0.4	0.2	164	2		0	120	7.3	2.5	0.5	0.2	0.0	0.3	21	4
Total Load	ding (Ib/	(day)							-									
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SR89 Database (103001)

Monday, February 18, 2002

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Page 6 of 22

SR89	Wa	ater		e	it	v Da	tab		٥									
Sample Point	Date	Method of Flow Meas.	Flow I (gpm)	Field L pH F	l a de la	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) (i	Mn D. ng/L) (n	, Mn 19/L) (AI mg/L)	D. AI (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
SR89	7/27/95		30	-	2.9				0	314	48.4		5.1	\mid	8.4		640	3
SR89	9/14/95		60		2.8				0	338	56.0		5.3		11.9		558	10
SR89	10/12/95				2.8				0	366	53.3		5.5		10.7		532	14
SR89	11/2/95				2.9				0	286	48.9	-	6.1		10.3		640	e N
SR89	12/13/95				3.0				0	368	90.4		5.5	_	10.8		814	4
SR89	1/10/96				3.1				0	308	94.1		6.2	-	9.6		962	26
SR89	2/22/96				3.0				0	206	30.4		5.2		6.9		449	m N
SR89	3/19/96				3.1				0	268	61.4	-	4.8		9.3		507	16
SR89	4/16/96				3.1				0	232	50.8		4.6		8.2		551	9
SR89	5/16/96				3.1				0	246	43.8		4.0		9.0		445	3
SR89	6/26/96		40		3.0				0	88	56.6		5.8		8.8		429	4 4
SR89	7/24/96	Estimated	50		3.2				0	254	70.0	-	5.5		7.8		711	9
SR89	8/15/96	Estimated	45		3.1				0	266	84.0	-	5.2		7.8		586	8
SR89	9/18/96	Measured	50		3.1		-		0	228	50.7		5,4	-	7.2		552	0
SR89	10/24/96	Measured	45		3.2				0	226	74.4		5.7		7.6		628	16
SR89	12/11/96	Measured	60		3.3				0	214	45.7		4.6		6.3		462	0
SR89	2/25/97	Measured	60		3.2				0	202	57.9		4.8		6.3		557	22
SR89	3/19/97	Measured	78		6.0				13	2	0.8		0.8		0.0		67	0
SR89	4/15/97	Measured	99		3.4				0	188	53.5		4.9	-	8.3		527	80
SR89	6/25/97	Measured	55		3.1				0	240	51.7		4.9		7.6		578	8
SR89	7/15/97	Measured	50		3.0				0	226	48.7		4.7		7.4		616	0
SR89	8/20/97	Measured	59		3.1				0	282	61.5		5.3		8.2		615	0
SR89	9/17/97	Measured	29		2.9				0	344	70.8		5.4		10.1		714	0
SR89	12/11/97	Measured	36		3.2				0	212	44.0		5.2	_	7.6		451	0
SR89	1/21/98	Measured	40	-	3.3				0	204	49.0		4.7		6.4		448	8
SR89	2/27/98	Measured	36		3.2				0	212	49.2		5.0		6.9		488	0
SR89	3/25/98	Assumed	64		3.2				0	204	49.3	-	4.8		6.6		455	00
SR89	5/19/98	Measured	145		3.1				0	184	33.2		4.3	-	6.9		482	4
2423	9/16/98	Estimated	30	-	3.1				0	266	52.4		4.4		7.0		790	0
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SR89 Database (103001)

Monday, February 18, 2002

Page 21 of 22

Alk (F) Alk (L) Acid E	Field Alk (F) Alk (I) Acid F	Spec. cond. Field Alk (F) Alk (L) Acid F	ield Lab Spec. cond. Field Alk (F) Alk (I) Acid F	Flow Field Lab Spec. cond. Field Alk (F) Alk (I) Acid Fi	Method of Flow Field Lab Spec. cond. Field Alk (F) Alk (I) Acid F	Method of Flow Field Lab Spec. cond. Field Alk (F) Alk (I) Acid Fi
Alk. (F) Alk. (L) Acid.	Field Alk. (F) Alk. (L) Acid.	Spec. cond. Field Alk. (F) Alk. (L) Acid.	ield Lab Spec.cond. Field Alk. (F) Alk. (L) Acid.	riow rield Lab Spec.cond. Field Alk (F) Alk. (L) Acid.	method of Flow Fleid Lab Spec.cond. Field Alk (F) Alk. (L) Acid.	Date Environd of Flow Field Lab Spect cond. Field Alk (F) Alk (L) Acid.
Alk. (F) Alk. (Field Alk. (F) Alk. (Spec. cond. Field Alk. (F) Alk. (ield Lab Spec. cond. Field Alk. (F) Alk. (Flow Field Lab Spec. cond. Field Alk (F) Alk	Method of Flow Field Lab Spec. cond. Field Alk. (F) Alk.	Method of Flow Field Lab Spec.cond. Field Alk (F) Alk
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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 (L)	D. Mn (mg/L)	AI (mg/L)	D. AI (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
SR89	3/31/99				3.0				0	236	39.0		5.4	F	9.7		134	0
SR89	6/16/99				2.9				0	266	33.1		5.4		9.5	-	510	0
SR89	9/14/99				2.8				0	344	57.0	+	5.2		10.1	-	803	4
SR89	6/7/01				2.7	1663	28		0	391	16.4	15.6	3.9	3.8	8.1	7.5	732	9
Σ	<u>i</u>		29		2.7	1663	28		0	7	0.8	15.6	0.8	3.8	0.0	7.5	67	0
Ä	ax		145		6.0	1663	28		13	391	94.1	15.6	6.2	3.8	11.9	7.5	962	26
Ā	bv		52		3.1	1663	28		0	249	52.3	15.6	5.0	3.8	8.1	7.5	559	9
Rai	nge		116		3.3	0	0		13	389	93.3	0.0	5.4	0.0	11.9	0.0	865	26
Total Load	/ql) gui	(day)			1				0	156	32.8	9.8	3.1	2.4	5.1	4.7		
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SR89 Database (103001)

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SR89	Water	ได้	la		y Da	tab)as	e									
Sample Point	Method of Date Flow Meas.	Flow (gpm)	Field PH	Р. Б.	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	AIK. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L) (Mn mg/L)	0. Mn mg/L)	AI Mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
56.1	6/7/01		6.9	6.7	192	21		17	0	0.4	0.1	0.4	0.4	0.1	0.1	51	5
W	lin		6.9	6.7	192	21		17	0	0.4	0.1	0.4	0.4	0.1	0.1	51	5
W	ax		6.9	6.7	192	21		17	0	0.4	5	0.4	0.4	0.1	0.1	51	5
A	Бл		6.9	6.7	192	21		17	0	0.4	0.1	0.4	0.4	0.1	0.1	51	S
Rai	nge		0.0	0.0	0	0		0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
Total Load	ing (lb/day)	 															

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SR89 Database (103001)

Monday, February 18, 2002

Page 1 of 22

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SR89	VV:	ater	ğ	J a		y Da	Itab	as	Φ									
Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	PH 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 I mg/L) (). Mn mg/L) (AI mg/L)	D. AI (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
60	6/7/01			6.5	6.4	344	. 22		8	0	0.8	0.1	1.0	1.0	0.1	0.1	146	3
	Min			6.5	6.4	344	23		8	0	0.8	0.1	1.0	1.0	0.1	0.1	146	2
	Max			6.5	6.4	344	22		80	0	0.8	0.1	1.0	1.0	0.1	0.1	146	2
	Avg			6.5	6.4	344	22		8	0	0.8	0.1	1.0	1.0	0.1	0.1	146	5
Ä	ange			0.0	0.0	0	0		0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
Total Loa	ding (Ib	/day)													-			

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SR89 Database (103001)

Monday, February 18, 2002

Page 2 of 22

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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)	AI (mg/L)	D. AI (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
63	6/7/01			6.0	6.0	349	22		9	-	2.4	1.3	1.0	1.0	0.1	0.1	161	9
M	lin			6.0	09	075	23		ŭ	•	ç	4	1	,	į			1
					;	222	1		C	-	А 4	<u></u>	0.1	1.0	0.1	0,1	161	9
M	ax			6.0	6.0	349	22		9		2.4	1.3	1.0	1.0	0.1	0.1	161	Ŷ
				0	0													>
t	ĥ			0	0.0	243	2		9	-	2,4	<u>ب</u>	1.0	1.0	0.1	0.1	161	9
μ α α	ann			C		C	c		<	C	0		-					
	2			5	5	5	>		S	þ	0	0.0	0.0	0.0	0.0	0.0	0	0
Total I vad	ina (Ibb	1																
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Monday, February 18, 2002

SR89 Database (103001)

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Sample Point Da	Method of te Flow Meas.	Flow (gpm)	Field PH	Ъв Р.	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 I mg/L) (. Mn mg/L)	AI (mg/L)	D. Al mg/L)	Sulfate (mg/L)	Susp. Solids (ma/L)
N. END OF WL (STA 4/9)	10,		2.6	2.8	1589	25		0	313	39.9		5.3		12.0		222	9
Mîn			2.6	2.8	1589	25		0	313	39.9		5.3	-	12.0		777	9
Max			2.6	2.8	1589	25		0	313	39.9		5.3		12.0		111	
Avg			2.6	2.8	1589	25		0	313	39.9		5.3		12.0		222	
Range			0.0	0.0	0	0		0	0	0.0		0.0		0.0		0	· c
Total Loading	(lb/day)															-	
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SR89 Database (103001)

Monday, February 18, 2002

Page 18 of 22

SR89	N,	ater	Ø	la	E	y Da	Itab)as	e									
Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	pH 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)	AI (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
N.E. END OF WL, F	4/9/01			3.3	3.7	884	23		0	219	89.1		4.1		6.7		541	74
	Mîn			3.3	3.7	884	23		0	219	89.1	-	4.1		6.7		541	74
	Мах			3.3	3.7	884	23		0	219	89.1		4.1	-	6.7		541	74
1	avg			3.3	3.7	884	23		0	219	89.1		4.1		6.7		541	74
ß	ange			0.0	0.0	0	0		0	0	0.0		0.0		0.0		0	0
Total Loa	ding (Ib	/day)							-					+				-

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SR89 Database (103001)

Monday, February 18, 2002

Page 19 of 22

DESIGN NARRATIVE

Purpose & Location

The proposed passive system will abate severely degraded drainage which has been monitored at point SR89. The discharge is located on State Game Lands No. 95, Washington Township, Butler County, PA. The geographical location of the project is approximately 41° 51' 50" north latitude by 79° 50' 52" west longitude.

This project is part of a comprehensive reclamation effort by numerous participants of the Slippery Rock Watershed Coalition.

Representative Water Chemistry

Water quality information has been interpreted from information for point SR89 in the CMRS report. In order to maximize potential treatment effectiveness, the highest observed values for flow, acidity, Fe, AI, and Mn and the lowest observed pH were used to calculate the size/volume of the passive system components. For the purposes of this project, the representative discharge water quality can be described as follows:

Flow	рН	Acidity	lron	Manganese	Aluminum
gpm		mg/L	mg/L	mg/L	mg/L
66	2.8	368	94	6	12

From the CMRS, the average parameter values are as follows:

Flow	рН	Acidity	Iron	Manganese	Aluminum
gpm		mg/L	mg/L	mg/L	mg/L
47	3.1	257	59	5	9

The pollutant loading based on the above average values can be summarized as follows:

Pollutant		<u>Loading</u>	
rondtant	<u>lbs./day</u>	lbs./month	<u>tons/year</u>
Acidity	145	4,415	27
Iron	33	1,014	6
Manganese	3	86	8
Aluminum	5	155	1

Design Specifications

Collection of Discharge

Drilling during piezometer installation indicated a clay material that is persistent throughout the construction area for the proposed vertical flow pond. A ground water monitoring program conducted 10/00 - 4/01 indicated water-bearing zones above and below the approximate horizon of the Brookville Seatearth.

The upper zone is generally associated with the Brookville coalbed with the lowest water levels controlled by the top of the clay material and elevated water levels associated with higher flow conditions encountered during the early spring. Water associated with this zone will be treated by the Vertical Flow Pond and other components of the passive system.

Due to the overlying clay material, the lower zone is probably under confined conditions in the vicinity of the construction area. Piezometers completed within this zone documented water levels that, during high-flow conditions, rise above the clay material, creating flowing artesian conditions around a utility pole and at borehole 30-10. Special care will be taken during construction in order to maintain the hydrologic integrity of the confining bed within the construction area.

In order to provide sufficient hydraulic gradient needed to allow the water to flow through th treatment media, the proposed outlet of the Vertical Flow Pond is designed to be generally below the water level associated with the upper water-bearing zone.

The basin for the Vertical Flow Pond will be formed by excavating to the claystone and subsequently intercepting the upper water-bearing zone. Sufficient open-water area will be included upslope of the treatment media to allow settling of solids. This area will act like a forebay.

Vertical Flow Pond(VFP)

Based on the above maximum parameter values, the amount of limestone required to treat the acidic, aluminum-bearing discharge is 2100 tons. AASHTO #1 90% CCE limestone is being used.

Each VFP cell will consist of a layered "Treatment Media" with extensive outlet plumbing. The treatment media for the VFP cells will be limestone only without compost. The amount of limestone to be used has been calculated using information from Hedin et al, 1994, using the representative water chemistry listed above.

Based on work completed by the Jennings Water Quality Improvement Coalition, the percent of iron and aluminum retained in a limestone-only vertical flow system was calculated. (Reference: Dunn, Margaret H., "The Interactive" July 1997, technical newsletter.) The average/median amounts of iron and aluminum retained in the pilot-scale tank at Jennings are 16% to 9% and 55% to 63%, respectively. For the purposes of this design, conservative percentages were used. It is assumed that 15% of the total iron and 75% of the total aluminum will be retained within the VFP limestone aggregate.

In order to remove the accumulated precipitates within the VFP, an extensive piping system will be installed. This will consist of 4" perforated SCH 40 PVC laterals placed on 4.5' centers with ½" perforations every 4.5' at approximately 30 degrees from top dead center on both sides.

The perforated pipe will be installed in two-layers with four separate cells on the upper laye and two cells on the lower layer. Each cell be further divided into two header sections which will be joined by a 6" tee located to enable so that an approximately equivalent total length of laterals will feed into each side of the tee. Each 6" tee will drain via a 6" pipe to a 6" slide-type gate valve. Prior to reaching the valve, an additional tee will be installed with a 4" pipe as the outlet riser.

This configuration will achieve two things. First: Under normal flow conditions the numerous perforations on the 4.5' grid will minimize flow velocity and encourage even flow distribution throughout the limestone to maximize efficiency. Second: The multiple cells per layer will allow for more effective flushing of the system. By opening only one cell at a time the flow velocity will be maximized during flushing to remove retained precipitates. The two-tier design will help to minimize the vertical distance the precipitates travel through the limestone; thus, decreasing the tendency for the development of preferential flow paths.

Each of the cells will discharge through an individual adjustable outlet riser. These outlet structures will initially be adjusted to assure even distribution of flow throughout the VFP. These structures will also allow monitoring of specific areas within the limestone layer. The monitoring data for each cell can then be used to make adjustments to the system to maximize treatment effectiveness.

Flushing events will be conducted on a periodic basis and/or as-needed. The valves will be opened one at a time with the discharge draining to the flush pond. The flush will be visually monitored and the valve will be closed after the discharge has become clear. Based on the field experience of Tiff Hilton, Mining Engineer, WOPEC, Lewisberg, WV, the flushing time will be approximately 15 minutes for each cell.

Aerobic Wetland(WL)

An aerobic wetland will be constructed to facilitate the oxidation, hydrolysis, and precipitation of metals. The sizing criteria for iron removal from alkaline mine drainage in an aerobic wetland is between 10-20 g per square meter per day(Hedin et al, 1994). Using the more conservative 10 g per square meter per day, the surface area of the wetland using only iron loading would be 36,433 SF. Using both iron and aluminum loadings at the design flow the total required surface area would be 41,000 SF. The current design of the aerobic wetland has at total of about 44,000 SF.

Sludge accumulation estimates are usually about 1 inch per year. Sufficient freeboard is incorporated into the wetland designs to facilitate the accumulation of approximately 25 years of sludge.

The wetland area will be vegetated with wetland plant species. This area will have ~0.5' of spent mushroom compost and ≤ 0.1 ' of water. The wetland will discharge via a rip-rap spillway.

Diverted Drainage

Untreated drainage from the easterly ditch along the abandoned railroad grade may be conveyed into the wetland to provide treatment. A cross-pipe may be installed to convey drainage above the construction area from the railroad ditch and the permanent diversion ditch to the westerly side of the abandoned railroad grade.



40 20 0 40 80	LEGEND	NOTES: Base map provided by PA DEP, BAMR, from aerial photography dated 2/16/99, contract #PA7134 Monitoring wells located by EDM survey by Youchak & Youchak (c. 11/00) All dimensions are in feet unless otherwise noted	Stream Restoration Through Coal Mine Drainage Abatement
EXISTING CONTOUR - INDEX	RIP RAP SPILLWAY (R-4)	All pipe is SCH 40 solid core with pressure rated fittings unless otherwise noted. All valves are to be slide gate-type (or equiv.) and are to be installed with protective structures. All E&S controls shall be installed prior to affecting the contributory drainage area.	Slippery Rock Creek Headwaters Project
EXISTING CONTOUR - INTERMEDIATE		System component specifications including elevations, dimensions, slopes, etc. may be revised based on field and/or other conditions. Call for all utilities: PA One Call 1-800-242-1776 Serial #1071633 Contour Interval: 2'	SHEET 1 OF 3 (PLAN VIEW)
PROPOSED CONTOUR - INTERMEDIATE PASSIVE TREATMENT SYSTEM COMPONENT	HIGH CCE (~90%) AASHTO #1 LIMESTONE	Monitoring Wells located within the construction area shall be properly backfilled. Location, size, etc. of diversion and/or collection ditches will be based on final erosion and sedimentation control plan.	PASSIVE TREATMENT SYSTEM DESIGN PLAN
EX. CULVERT/WATER STRUCTURE	DESIGN SLOPE SPECIFICATION		SR89 DISCHARGE
WATER	← ♀ → BERM WIDTH DIMENSION		Slippery Rock Watershed Coalition
TRAILS	A A' CROSS-SECTION		Stream Restoration Incorporated Washington Twp., Butler Co., PA
UTILITY POLE	30-01 MONITORING WELL		Scale: 1" = 40' Date: 12/2001 BioMost, Inc., Cranberry Twp., PA



	А	1' MIN. (FROM INVERT OF UPPER TIER TO TOP OF LOWER TIER)
	В	1.5' (FROM TOP OF LIMESTONE TO INVERT OF UPPER TIER)
	С	10' MIN. (FROM UPSLOPE EDGE OF LIMESTONE TO END OF UPPER TIER LATERAL)
	D	1.0' (DESIGN WATER DEPTH)
Γ	Е	1.0' (MINIMUM LIMESTONE THICKNESS)
Γ	F	0.25' (BEDDING STONE THICKNESS - 0.25' AASHTO #57)



<u>4" </u>	Perf Upp	er Tier		<u>4''</u>
(St	arting from	North)		(8
Lateral #	Sector	Length (ft)	-	Lateral #
1	1	34.1	1	1
2	1	48.7	1	2
3	1	48.0		3
4	1	46.9	1	4
5	1	45.0	1	5
6	1	43.2		6
7	1	41.4	1	7
8	1	39.6		8
9	1	37.8	1	9
10	1	35.9	1	10
11	1	49.4	1	11
12	1	50.2		12
13	1	50.9		13
14	1	51.6	1	14
15	1	52.3	1	15
16	1	53.0	1	16
17	2	53.7	1	17
18	2	54.4	1	18
19	2	55.2	1	19
20	2	55.9	1	20
21	2	56.6	1	21
22	2	57.3		22
23	2	58.0		23
24	2	59.1	1	24
25	2	60.1	1	25
26	2	61.2	1	26
27	2	62.3		
28	2	63.5		
29	2	64.7		
30	3	65.9		
31	3	67.1		
32	3	68.4		
33	3	69.6		
34	3	70.8		
35	3	71.4		
36	3	72.5	-	
37	3	73.6	-	
38	3	74.8	-	
39	3	75.8		
40	4	/6.8	-	
41	4	77.9	-	
42	4	79.0		
43	4	80.1		
44	4	(1.5		
45	4	09.8		
40	4	02.1 54.4		
4/	4			
40	4	40.7		
49	4	31 S	-	
	4	31.3		

NOTES: Base map provided by PA DEP, BAMR, from aerial photography dated 2/16/99, contract #PA7134 Monitoring wells located by EDM survey by Youchak & Youchak (c. 11/00) All dimensions are in feet unless otherwise noted. All pipe is SCH 40 solid core with pressure rated fittings unless otherwise noted.	
All valves are to be slide gate-type (or equiv.) and are to be installed with protective structures. All E&S controls shall be installed prior to affecting the contributory drainage area. System component specifications including elevations, dimensions, slopes, etc. may be revised based on field and/or other conditions.	Stream Restoration Through Coal Mine Drainage Abatement
Call for all utilities: PA One Call 1-800-242-1776 Serial #1071633 Contour Interval: 2'	Slippery Rock Creek Headwaters Project

SHEET 2 OF 3 (DETAILS)

PASSIVE TREATMENT SYSTEM DESIGN PLAN

SR89 DISCHARGE

Slippery Rock Watershed Coalition in cooperation with Stream Restoration Incorporated

Washington Twp., Butler Co., PA Scale: 1" = As Shown Date: 12/2001 BioMost, Inc., Cranberry Twp., PA

103001/nt

LEGEN	

EXISTING CONTOUR - INDEX
EXISTING CONTOUR - INTERMEDIATE
PROPOSED CONTOUR - INDEX
PROPOSED CONTOUR - INTERMEDIATE
PASSIVE TREATMENT SYSTEM COMPONENT

WATER

LENGTH AS PER TABLE V	/FP UPPER TIER LATERALS - 4" PERFORATED*
LENGTH AS PER TABLE V	/FP LOWER TIER LATERALS - 4" PERFORATED*
U U U L L L	IPPER TIER HEADERS - 4" SOLID IPPER TIER MAINS - 6" SOLID OWER TIER HEADERS - 4" SOLID OWER TIER MAINS - 6" SOLID

*ALL LATERALS PLACED ON 4.5' CENTERS AS SHOWN WITH (2) 1/2" PERFORATIONS ON 4.5' CENTERS 30° FROM TOP











HORIZONTAL SCALE: 1" = 20' VERTICAL SCALE: 1" = 10'

<u>NOTES:</u> Geologic and groundwater information provided for portion of cross section where drilling data provided sufficient information.

Existing topographic information taken from mapping provided by PA DEP, BAMR, generated from aerial photographs dated 2/16/99, contract #PA7134.

Proposed topographic information based current design layout and is subject to change based on field and/or other conditions.

*Flush pond bottom elevation will be raised on upslope side in order to protect the integrity of the underlying in-place clay material. The in-place clay material is not to be compromised during construction; i.e., the total volume of the flush pond may be reduced in order to maintain the impermeability of the clay material.

Stream Restoration Through Coal Mine Drainage Abatement

Slippery Rock Creek Headwaters Project

SHEET 3 OF 3 (CROSS SECTIONS)

PASSIVE TREATMENT SYSTEM DESIGN PLAN

SR89 DISCHARGE

Slippery Rock <u>Watershed Coalition</u> in cooperation with Stream Restoration Incorporated Washington Twp., Butler Co., PA Scale: As Shown Date: 12/2001 BioMost, Inc., Cranberry Twp., PA

103001/nts

LEGEND

 EXISTING GRADE		PROPOSED DESIGN WATER ELEVATION - VERTICAL FLOW POND
 PROPOSED GRADE		GEOTEXTILE (STABILIZATION TYPE)
 HIGH CCE (~90%) AASHTO #1 LIMESTONE		TOP OF IN-PLACE CLAY MATERIAL
 UPPER TIER LATERALS - 4" PERFORATED		BOTTOM OF IN-PLACE CLAY MATERIAL
 LOWER TIER LATERALS - 4" PERFORATED		BEDDING STONE (AASHTO #57)
 UPPER TIER HEADERS - 4" SOLID	✓ 1241.0 (04/24/01)	HIGH WATER LEVEL ASSOCIATED WITH BROOKVILLE SEATEARTH
 LOWER TIER HEADERS - 4" SOLID	☑ 1235.6 (11/06/00)	LOW WATER LEVEL ASSOCIATED WITH BROOKVILLE SEATEARTH
 UPPER TIER MAINS - 6" SOLID		
 LOWER TIER MAINS - 6" SOLID		

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

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Keywords: Acid mine drainage, passive treatment, anoxic limestone drain, vertical flow wetland, macroinvertebrates, periphtyon, stream restoration

Abstract

A 70 km² area in the headwaters of Slippery Rock Creek in Western Pennsylvania is impacted by acid mine drainage (AMD). Twelve stations, two of which are in unimpacted control streams, were sampled in fall 1999, spring 2000, fall 2000, spring 2001 and fall 2001 to monitor changes in water chemistry resulting from continued passive treatment in the watershed. Seven of the 12 sites were monitored for changes in epilithic and epipelic algae, and in macroinvertebrates in riffle areas. Values for pH and alkalinity in some tributaries and sites in the lower watershed increased slightly during the 1999-2001 period. Since monitoring began in 1995, there have been long term increases in alkalinity in the Seaton Creek tributary and in the two sites lowest in the watershed (65 and 67), which reflect the substantial restoration efforts in the Seaton Creek drainage and upstream sites in the main stem during this period. Overall, pH and alkalinity values in the streams are fairly good, however they can temporarily decrease during periods of high flow, presumably through flushing out of mine pools. Although concentrations of dissolved zinc and nickel have decreased in Seaton Creek, values of dissolved iron and manganese remain above EPA standards for organisms and could be limiting biological recovery.

The percentages of acidic indicator taxa of benthic algae are higher at AMD impacted sites than the reference sites, however the reduction in their relative abundance since 1995 at several sites is a sign of improving conditions. Macroinvertebrates remain severely impacted at AMD sites. Macroinvertebrate density and richness at the impacted sites remain well below those for the reference streams. One of the most important factors limiting macroinvertebrate recovery is probably the high amount of fine sediments in the watershed that make an extremely poor substrate for the invertebrates in the most of main stem. Despite these problems, AMD sensitive taxa (i.e., mayflies, stoneflies and caddisflies) are beginning to be found in low numbers on hard substrata, downstream in the watershed (Site 65).

The continued high concentrations of sulphate in the streams indicates that mine drainage still enters the watershed, but the concurrent improvement in alkalinity demonstrates that treatment systems are successfully reducing AMD impacts in the watershed. This coupled with the slightly improving trends in the benthic algal flora and invertebrate fauna suggests further recovery in the watershed as future restoration efforts occur. Recommendations are for a better understanding of the hydrology of the watershed, improving the substrate quality in the streams, and the need for experimental work to determine specifically which chemical factors are limiting the recovery of the biota.

2

macroinvertebrates more than low pH or alkalinities, and that complex interactions in the hydrology of the mine pools may have caused temporarily harmful concentrations of many chemical parameters in the streams. In addition, much of the substrate at the impacted sites was dominated by clay, which is a very poor substrate for macroinvertebrates (DeNicola and Stapleton 1999).

There has been more treatment of AMD and restoration of the watershed since 1999. On the main stem of Slippery Rock Creek, 1 more passive treatment system was completed in 2000, with another nearing completion. There has also been extensive recent restoration in Seaton Creek, a major tributary of Slippery Rock Creek in the headwaters, with 4 sites of land reclamation and several large vertical flow systems installed. As a result, there are now currently approximately 12 passive treatment systems in the headwaters of Slippery Rock Creek treating about 500 million gallons of water a year (Fig 1). This removes about 190 tons/yr of acidity, 8 tons/yr of Al and 150 tons/yr of Fe (see the Watershed Coalition web site, www.srwc.org). The purpose of the present study was to continue monitoring of the stream sites twice a year from the fall of 1999 through the fall of 2001 to determine if conditions in the watershed were improving as a result of the increase in restoration efforts. Note, there were two funding sources for monitoring during this period, a Bureau of Land and Water Conservation Nonpoint Source 319 Project that funded the restoration efforts at discharge SR89, and a Growing Greener Grant that funded restoration for SR 96. Since the monitoring study was continuous, data for the entire 1999-2001 period are provided in this one report. Also, we report some long term trends in the streams for 1995-2001.

In addition to monitoring, a set of experiments that examined the relative roles of substrata and aqueous affects of AMD on invertebrates and algae in Slippery Rock Creek was completed in 2000. Information on this study is provided in a separate, self-contained, attached document, which has been accepted for publication in the journal *Environmental Pollution*.

Methods

Detailed methods were provided in the QA/QC work plan originally written for this study in 1996 and are available from the authors or the PA DEP. Below is a brief summary of the methods. Sample dates for analyses for each parameter are given in Table 1.

Study Design

Twelve sites in the watershed (Fig. 1) were sampled for selected chemical parameters in fall 1999, spring 2000, fall 2000, spring 2001 and fall 20001 (Table 1). Seven of the sites are in the main stem of Slippery Rock Creek (2-4th order streams) within the headwaters area and impacted by AMD (sites 44, 46, 60, 63, 64, 65 and 67), 3 are AMD impacted tributaries (49, 62, and 68), and 2 sites are in "control" or reference streams that are unimpacted by AMD (Fig. 1). One of the control streams is a 1st order unimpacted tributary within the headwaters (Site 61), the other is Wolf Creek, a 4th order stream that is in the Slippery Rock Creek watershed but not in the headwaters area. Biological samples were taken at a subset of the sites (44, 46, 60, 61, 65, 67)

4

Results and Discussion

The complete set of values for all water chemistry parameters and discharge on each sample date are given in Tables 2 and 3

pH, alkalinity and acidity

Pennsylvania water quality standards cite pH values below 6 has being detrimental to aquatic life, although severe effects usually are found below 5.5. Values for pH in the headwaters ranged from 4.5 to 7.8, with values of 5.5 or lower occurring on some dates from Sites 44, 62, 64 and 68 (Fig. 2). State water quality standards list impacts occurring below an alkalinity of 20 mg/l for most streams, and sites in the headwaters area almost always below this (Fig. 3). However, the low alkalinity at the small reference stream in the headwaters is also occasionally below 20 mg/l, suggesting a naturally low buffering capacity of the geology of the area in general. The most downstream sites in the headwaters, 65 and 67, were generally greater than this threshold during the study period (Fig. 2) Alkalinity and pH values were substantially higher in the large reference stream, Wolf Creek, primarily because it is in a different geologic group than the headwaters (Potsville vs. Allegheny) with more tributaries intersecting the Vanport Limestone outcrop geology. Acidity values were quite variable, reflecting to some extent the difficulties involved in measuring acidity accurately (APHA 1989). Overall acidities were highest at Sites 46/49, 63 and 64, but often values were similar to those found in the small reference site, 61 (Table 2).

Temporal trends in pH, acidity and alkalinity at each site during the 2 year period covered by this report are difficult to discern. However, from 1999-2001 there do appear to be some increases in pH and alkalinity at Sites 62, 64, 65 and 67 (Figs. 2 and 3). The recent improvement in pH and alkalinity at Site 62 may be related to the construction an anoxic limestone drain in the area in 1998. While this treatment system is a short distance downstream from Site 62, it increased the flow from the AMD discharge, which perhaps lowered the mine pool in the deep mine in the hillside. This may have dried up small discharges above Site 62 that were coming out of the same mine pool. Longer term trends based on monitoring at the sites since 1995 also show improvements. Site 68 is on Seaton Creek, and drains an area that has received substantial restoration since 1998. For the time period 1995-2001 there are positive increases in alkalinity and pH at this site (Figs. 4 and 5). Sites 65 and 67 are at the bottom of the headwaters and therefore changes in their water chemistry should reflect the overall impact of restoration efforts in the entire watershed. Site 67 is upstream of the Seaton Creek inlet and Site 65 below. Both these sites have shown increases in pH and alkalinity since 1995, which presumably reflects the positive affects of restoration on water chemistry in the headwaters (Figs. 6-9). While the significance of these long term trends were not tested statistically for this report, they do indicate a trend of improving water quality.

Sulphate, conductivity and dissolved oxygen

Sulphate and conductivity are good general chemical indicators of AMD and were highest

limiting biological recovery at some sites in the watershed.

Mean values of dissolved aluminum at impacted sites were similar to values for reference sites, generally less than 0.3 mg/l (Table 3) and haven't change much since the previous monitoring period. Pennsylvania aluminum standards depend on the species of organism, the standard for New York is 1.0 mg/l total Al, and is exceeding at several sites in the watershed (Table 3). Nontoxic silicon is associated with aluminum as aluminum silicates in minerals, and had similar trends in concentrations as aluminum in the aqueous samples

Dissolved lead was lowest at the small reference site, 61, but other sites, except 68, had similar concentrations to Wolf Creek (Table 3). There are no biota standards for lead in surface water for PA, and EPA standards depend on the organism.

Concentrations of soluble zinc were generally higher at the impacted sites than the reference sites from 1999-2001 (Table 3), however most values are below the toxic threshold minimum, 0.1 mg/l. During the 1995-1999 monitoring period mean concentrations of dissolved zinc were quite high (near or above 0.1 mg/l) for Sites 63 and 68 and seem to have decreased since then.

In general, concentrations of soluble nickel and cadmium at the impacted sites were similar to values at the reference sites, indicating little impact (Table 3). Average nickel concentrations were very high at Site 68 (> 0.1 mg/l) during the 1995-1999 monitoring period and have drop significantly since then. Cadmium concentrations are similar to what they were in 1995-1999 (Table 3 and DeNicola and Stapleton 1999).

Aqueous concentrations for both calcium and magnesium were lowest at the small reference stream (Site 61). Concentrations in Wolf Creek were similar to impacted sites except for Sites 68 and 65, which were considerably higher (Table 3). One would expect higher levels of calcium and magnesium at lower pH sites from the dissolution of their alkaline minerals. Higher calcium levels in the watershed could also result from dissolution of calcium from limestone in ALD's and vertical flow systems. Given the high sulfate levels in the impacted streams (200-700 mg/l), high calcium may result in precipitation of gypsum (CaSO₄) in the streams. These trend are similar to what they were during the 1995-1999 monitoring period (DeNicola and Stapleton 1999).

Effect of discharge on water chemistry:

Although there appears to be a trend in improvement in some water quality parameters, patterns are difficult to establish because flow conditions can influence concentrations. For example, alkalinity at Sites 60 and 64 in the middle of the watershed, tended to decrease at high discharges during the period 1995-2002 (Figs 14 and 15). A similar relationship exists for other sites as well. Changes in pH and iron concentrations also tend to be related to flow at some sites, but the trends were not as clear as for alkalinity. Dills & Rogers (1974) found high surface runoff during wet periods often increased dilution of AMD inputs, however we found the opposite.

that increase the species richness of the sample. Comparison of the upstream impacted sites to the small reference stream, 61, indicates that richness values were variable but similar among the sites for most dates. In fact, richness was higher at Sites 44 and 46 than Site 61 on many dates (Figs. 18 and 19). Serious impact on benthic algal richness and diversity does not begin to appear until below pH 4.5 (DeNicola 1999), which rarely occurred at any of the sites. However, many species of diatoms have narrow pH tolerances and are good indicators of pH, thus while there is little change in diversity there was a shift in species composition at the AMD impacted sites.

Comparing the similarities in average species composition for the whole study (dates pooled for each site) among sites indicates that Wolf Creek is most different from all other sites in both epilithic an epipelic species composition (Tables 4 and 5). Dominant taxa in both the epilithon and epipelon in Wolf Creek were the diatoms *Navicula gregaria* and *Navicula lanceolata* (Tables 4 and 5). There were also many species in this diverse flora that are typical for a clean water, moderately productive, high pH stream. The cyanobacteria, *Phormidium* is a dominant taxon at the other sites, indicating it was tolerant of their AMD impacts. Several types of cyanobacteria have been found to be tolerant to heavy metals (Genter 1996), but generally not grow well in very acidic conditions. Diatom taxa typical of low pH are species of *Eunotia* and *Anomoeonies*, which also can be abundant in severely impacted AMD streams (Verb and Vis 2000, Warner 1971). These taxa are generally most abundant at Site 60. Site 61 does have several acid tolerant diatoms, which is not surprising given its pH and low alkalinity. Generally these taxa are less abundant and *Phormidium* more abundant at Site 60 compared to the AMD impacted sites.

Overall, the species composition of epilithic and epipelic algae at the AMD affected sites has fewer acidic diatoms than in 1995-1999, indicating some improvement in the past few years. For example, Sites 46 and 60 have less than half the percentage of acidic epilithic diatom taxa than they contained in 1995-1999. A similar decrease occurred for Sites 65 and 67, although smaller. At the same time, the percentage of acidic taxa at Sites 44 and 61 has not changed from 1995-2001, which is to be expected since 44 is upstream of all installed treatment and 61 is a reference stream.

To examine whether benthic algae indicates substantial improvement during the 1999-2001 period, changes in the abundance of acid indicator species as a percentage of only diatoms were examined. For epilithic diatoms, sites 44, 46 and 60 had overall the highest percentage of acid indicator species, indicating they are the most AMD impacted sites (Table 6). There is much variability over time at each site, however, there appears to be a bit of a decrease in the percentage of acidic diatom species at Site 60 and perhaps Site 46. Although this is not a significant statistical relationship it might denote a future trend of biological improvement at some of the AMD impacted sites. The percentage of acidic diatoms is higher for all sites in the epipelon, and there is no indication of a decrease in their abundance at any of the sites for the past 2.5 years (Table 7). al. 1988). While stoneflies and caddisflies are more tolerant of low pH, they are in general considered indicators of good water quality. As a result the EPT index (the number of mayfly + stonefly + caddisfly taxa) is widely used to assess water quality. The value of the EPT index has increased at Site 65 over time during the period of 1999-2001 (Table 9). Moreover, it has increased at this site from the 1995-1999 monitoring period. While the number of EPT taxa and densities of invertebrates were low at the site relative to the reference, there has been an improvement in the number of clean water taxa found at site. Although represented by only 1-2 individuals, the presence of the mayflies *Serratella* and *Caenis*, the caddisflies *Pycnopsyche* and *Chimarra*, and the stonefly *Paracapnia* are indications that conditions have improved at Site 65 in the past 7 years (Appendix II and DeNicola and Stapleton 1999).

The low density and taxa richness of the benthic macroinvertebrates in riffles at AMD impacted sites relative to the control sites corresponds to many other studies of AMD effects (Dills and Rodgers 1974, Letterman and Mitsch 1978). Based only on the average pH and alkalinites, the Slippery Rock headwaters should be able to support a larger and more diverse invertebrate fauna (Hoehn and Sizemore 1977). However, some of the chemical data indicated that concentrations of heavy metals are near or at the toxic threshold for stream fauna, and probably are having the greatest affect on invertebrates. There is also great variability in water quality over time, and the overall low invertebrate densities probably result from impacts during periods of high AMD input. In addition, mining disturbance in a watershed greatly increases soil erosion, which alone can have as large or larger a detrimental affect on invertebrates as water chemistry (Hoehn and Sizemore 1977). The watershed in headwaters area of Slippery Rock Creek has been highly disturbed from mining and has a lot of naturally occurring clay. The increased sediment load in the steams together with iron precipitates from AMD bury substrate and reduce invertebrate density and diversity. Sites such as 46 have deep clay and silt deposits that are extremely unstable and poor habitats for invertebrates. It is probably the combination of burial by fine sediments and toxic levels of metals at certain times during the year that are still affecting the macroinvertebrates fauna in the treatment area. The relatively hard substrata of parts of Site 65 might be one reason why there has been some improvement in the types of macroinvertebrates found at this site.

Overall Assessment of Water Quality at the Sample Sites in Slippery Rock Creek

The chemical conditions in the Slippery Rock Creek watershed have generally improved in in the short and long term. From 1999-2001 there has been improvement in the lower watershed and some tributaries in pH and alkalinities. In addition, the restoration efforts in the Seaton Creek tributary have resulted in increased pH and alkalinity in that stream since 1995. The improvement in these parameters in the lower watershed (Sites 65 and 67) since 1995, indicate an overall neutralization of acid impacts by the treatment systems. The continued high concentrations of sulphate indicates that mine drainage still enters the watershed, but the concurrent improvement in alkalinity demonstrates that treatment systems are successfully reducing AMD impacts in the watershed.

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<u>Date</u>	Code	pH, Alk & Dis. <u>Metals</u>	Total Aq. <u>Metals</u>	<u>Algae</u>	Surber
21Oct99	Fall99	x	x	x	x
23Mar00	Spr00	x	x	x	x
19Sept00	Fall00	x	x	x	x
8Mar01	Spr01	x	x	x	x
25Sept01	Fall01	x	x	x	x

Table 1. Sample dates and codes for biological and chemical parameters.

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Table 2 Cont.

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Site	Date	Temp C	рН	Alk (mg/l)	Acd (mg/l)	SO4 (mg/l)	DO (mg/l)	Cond (mS/cm)	Flow (m3/s)
44	9/25/01	14	6,64	25.6	12.9	70	9	0.39	0.023
46&49	9/25/01	13	6.73	31.5	10.2	170	8	0.50	0.075
60	9/25/01	12	6.4	22	12.8	140	8	0.50	0.117
61	9/25/01	13	6.78	18	11	32	10	0.14	140 0.001
62	9/25/01	13	6.27	15.4	16.4	100	11	0.38	0.073
63	nd	nd	nd	nd	nd	nd	nd	nd	nd
64	9/25/01	14	5,65	10.3	25.3	175	5	0.52	nd
65	9/25/01	14	6.63	31	· · 8.9	380	10	0.82	0.351
67	9/25/01	15	6.76	31	12	165	9	0.56	nd
68	9/25/01	13	6.71	32.5	13.7	490	8	1130 1.13	0.073
· WC	9/25/01	14	8.3	183	0	77	11	0.50	0.479
able 3 Cont.									
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	ູ ເບ	លី	លី	5	8	ß	ß	g	2	8	8	8	5	5	ð	8	5	8	8	8	8	5	8	8
Zinc Total (mg/l)		<i></i>	<u>.</u>	ō	õ	õ	00	ō	õ	ā	ä	ē	ö	ö	~	Ö	q q	ä	0.0	ä	ö	o -	a -	o
Nickel Total (mg/i)	SN	SZ	SZ SZ	80	0.0	8	0.015	0.0	0.0	0.0	80	0.0	0.0	0.025	ž	00	0.0	00	0	ö	ö	00	9.9	0 0
Lcad Total (mg/l)	NS	SN	SS	0,22	0.12	0.19	0.195	0.23	0.35	0.21	0.56	0.29	0.16	0.21	ŝ	0.22	0.13	0.21	0.305	0.32	0.39	0.29	0.47	0.26
admlum Total (mg/l)	SN	SS	SN	0.02	0.0	0 8 8	0.025	8	<u>8</u>	8	0.07	0.04	0.0	0.025	S	0.0	0.0 20	0.0	0.035	0.0	9.6	9.9	0.05	0.03
Silicon C Tottal (mg/l)	SN	Ň	ş	4.27	3.53	4.84	3.78	4.17	4.18	3,82	4.58	1.58	3,14	2.87	SN	53	2.26	2.43	2.21	2.73	2.42	2.88	2.14	1.23
Total	NS	SN	SN	8.52	3.40	8.28	8.51	9.17	18.08	9.28	35.73	6.53	5.55	8.355	SN	7,32	224	5.91	7.805	8.01	16.26	9.20	22.48	5.12
alclum Ma fotal m mg/l) (sz	SN	SN	28.42	7.61	21.91	24.885	29.24	57.58	28.35	107.91	40.31	19.84	29,24	ş	30.68	5.88	19.64	31.595	29.78	5 5.52	34.34	66.32	24.28
Total ()	SN	Sz	SN	0.59	0.19	0.90	0.58	0.83	2.78	0.78	6.61	0.07	0.98	1.745	SN	0.23	0.10	0.83	22	1.53	1.87	0.57	3.11	0.05
ron Ma otxal ee ng/l) (i	NSN	SS	SN	2.20	0.28	9. 1	1.41	0.56	1.60	0.44	3.07	0.29	1.68	1.225	SN	ä	0.44	1.35	1.645	1.0 8	0.53	0.69	0.60	0.11
alnum tat (n (n (n	SZ	SS	SN	2.45	1.58	8.30	2.035	2.13	3.46	2.37	2.44	1.48	0.70	1.39	SN	6.00	1.08	1.67	1.55	1.96	3.00	3.53	3.61	1.38
	8	5	ŝ	8	8	5	25	8	2	5	8	δ	07	80	SS	8	5	<u>80</u>	8	8	ខ	ġ	80	5
Zinc Solubi (mg/l	о	đ	_	ø	o	o	0	o	o.	.o	G	o	o	o		Ô	Ģ	0	0	0	•	•	°	0
Nickel Soluble (mg/l)	0.04	0.03	SN	0.02	0.01	0.8	0.025	0.03	9 2 2	0.02	0.07	0.02	0.04	0.05	SN	0.01	0.01	- 0.04	0.015	0.03	80	0.02	20.0	0.0
Lead Soluble (mg/l)	0.21	0.28	SS	0.21	0.11	0.18	0.235	0.27	0.37	0.23	. 0.57	0.28	0.34	0.5	SN	0.34	0.11	0.34	0.435	0.32	0.50	0.44	0.94	0.27
admium Soluble (mg/l)	0.02	0.0	SN	0.0	0.0	0.02	0.02	80	8 8	80	0.07	0.03	0.05	0.07	NS	0.05	0.02	0.05	90.0	0.05	0.07	0.06	0.12	0.04
Silicon C Soluble :	4.51	4.73	SN	3.86	3.01	3.88	3.865	4.24	4.00	3.85	4.85	1.52	9.08	9.23	SZ	3.87	4.35	7.21	4.985	5.07	4.17	5.75	6.13	2.23
ineeiju m Solubis ((mg/l)	10.78	11.48	SN	9.79	3.77	9.33	9.37	9.75	19.35	9:98	38.93	9.01	20.29	34,88	SN	18.05	7.05	25.30	25.53	20.07	38.40	30.10	92.87	13.92
Solution M M M M M M M M M M M	27.30	37.70	SN	28.42	7.87	21.87	28.045	32.82	89.11	31.77	119.91	44.31	71.47	121.1	SN	73.36	17.10	78.08	103.115	74.50	130.78	108.50	270.98	67 06
angana ba ba ba ba ba ba ba ba ba ba ba ba ba	2.38	1.30	SN	0.68	0.21	1.01	0.67	0.93	3.14	0.85	7.30	0.09	3.26	6.685	SN	0.39	0.29	3.31	0.645	3.69	3.99	1.83	13.14	0.09
M norl oluble	1.41	1.52	NS	1.81	0.08	0.44	1.235	0.37	1.16	0.18	2.57	0.10	5.43	2.42	SN	0.39	0.28	3.8	1.515	1.43	0.25	0.48	1.32	0.04
minum olubic S ng/i) (i	0.28	0.26	SN	0.31	0.28	0.29	0.31	0.30	0.27	0.27	0.26	0.26	0.28	0.26	SN	0.25	0.24	0.26	0.255	0.30	0.25	0.24	0.27	0.24
ation Guarter St	44 Spring 01	46 Spring 01	49 Spring 01	60 Spring 01	61 Spring 01	62 Spring 01	63 Spring 01	84 Spring 01	65 Spring 01	67 Spring 01	B8 Spring 01	WC Spring 01	44 Fall 01	46 Fall 01	49 Fall 01	60 Fall 01	61 Faul 01	62 Fail 01	63 Fall 01	64 Fall 01	65 Fall 01	67 Fall 01	68 Fall 01	WC Fall 01
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Run: Relative abundance of taxa in epipelon 1999-20001, pooled by date. Relative abundnace Taxa in bold are indicative of acidic conditions.

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Label	Site 44	Site 46	Site 60	Site 61	Site 65	Site 67	Wolf Creek
Species ID							
Ach. lanceolata	0.0598	0.1099	0.1543	0.1271	0.1539	0.2797	0.0193
Amp. perpusilla	0.0000	0.0000	0.0000	0.0000	0.0013	0,0000	0.0602
Eun. minor	0.0023	0.0574	0.1152	0.0291	0.0768	0.0846	0.0013
Frag. const. ven	ter0.0000	0.0006	0.0121	0000-0	0.0210	0.1143	0.0233
Gomp. parvulum	0.0395	0.0308	0.0117	0.0328	0.0356	0.0275	0.0123
Nitz palea	0.0082	0.0693	0.0237	0.0056	0.0626	0.0546	0.0559
Phormidium sp.	0.7163	0.2423	0.1257	0.5183	0.1534	0.0566	0.0066
Nav. gregarica	0.0036	0.0217	0.0011	0.0028	0.0243	0.0104	0.1720
Nav. lanceolata	0,0000	0.0000	0000-0	0.0010	0.0040	0.0012	0.0443
Anom. vitrea	0.0010	0.0574	0.2728	0.0033	0.1419	0.0442	0.0000
Eun. exigua	0.0320	0.0722	0.0522	0.0430	0.0797	0.0100	0.0006
Euglena sp.	0.0000	0.0417	0,0000	0,0030	0.0000	0.0000	0.0024
Diversity HE	1.4803	2.8956	2.6351	2.1550	2.9905	2.8813	3.5156
Richness N(0)	69.0000	55.0000	62:0000	66.0000	75.0000	56.0000	77.0000

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Table 7

Change in percent of epipelic diatoms that are acid indicators.

<u>Site</u>	-	<u>Fall99</u>	<u>Spr00</u>	<u>Fall00</u>	<u>Spr01</u>	<u>Fall01</u>
Site Site Site Site Site Site	44 46 60 61 65 67	$24.54 \\ 10.63 \\ 20.33 \\ 11.21 \\ 13.77 \\ 14.10$	20.27 28.00 39.40 9.30 27.12 20.20	20.79 42.57 17.33 22.33 23.38 7.32	22.00 38.24 39.33 25.00 28.67 12.00	20.79 13.67 16.07 22.50 14.67
Wolf	Creek	0.00	0.00	0.00	0.00	0.98

2.52

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Change in Alkalinity at Site 65 from 1995-2001

Figure 7



Figure 3

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Change in Alkalinity at Site 68 from 1995-2001

Figure 5



A = ALD(yr const.) W= Wetland (yr const.) V = Vertical Flow (yr const.) C = Coal refuse removal (yr const.) U= Under construction



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Figure Captions

- Fig. 1. Map of the hadwaters of Slippery Rock Creek indicating the location of sample sites, passive treatment systems for acid mine drainage discharges, and the area of land reclamation. Wolf Creek is approximately 30 km west of the headwaters and not on the map.
- Fig. 2. Change in pH at the sample stations.
- Fig. 3. Change in alkalinity at the sample stations.
- Fig. 4. Temporal change in pH at Site 68 (Seaton Creek) for the period 1995-2001. Best fit line, not tested for significance.
- Fig. 5. Temporal change in alkalinity at Site 68 (Seaton Creek) for the period 1995-2001. Best fit line, not tested for significance.
- Fig. 6. Temporal change in pH at Site 65 for the period 1995-2001. Best fit line, not tested for significance.
- Fig. 7. Temporal change in alkalinity at Site 65 for the period 1995-2001.Best fit line, not tested for significance.
- Fig. 8. Temporal change in pH at Site 67 for the period 1995-2001.Best fit line, not tested for significance.
- Fig. 9. Temporal change in alkalinity at Site 67 for the period 1995-2001. Best fit line, not tested for significance.
- Fig. 10. Change in dissolved iron concentration at the sample stations.
- Fig. 11. Temporal change in dissolved iron at Site 67 for the period 1995-2001. Best fit line, not tested for significance.
- Fig. 12. Temporal change in dissolved iron at Site 65 for the period 1995-2001. Best fit line, not tested for significance.
- Fig. 13. Temporal change in dissolved iron at Site 68 for the period 1995-2001. Best fit line, not tested for significance.
- Fig. 14. The relationship between discharge and alkalinity at Site 60. Best fit line, not tested for significance.
- Fig. 15. The relationship between discharge and alkalinity at Site 64. Best fit line, not tested for



Changes in pH at Site 67 from 1995-2001

Figure 8



Figure 10



Changes in Soluble Fe at Site 65 from 1995-2001

Figure 12



Change in Alkalinity with Discharge at Site 60

Figure 14



Figure 16



Species Richness for Epilithic Algae

Figure 18







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Appendix I

A. Taxa names and codes for algae

B. Relative abundance of epilithic algal taxa at each site on each date.

C. Relative abundance of epipelic algal taxa at each site on each date.

	Denticula sp.	365				
	Diatoma vulg hiemalie	174				
(Diploneis sp	216				
(Euglena	349				
		209				
	Euro curvata y capitata	310				
	Eun elegans	241				
	Eun exigua	238			*	
	Eun implicata	268				
	Eun intermedia	267				
	Eun musicola triden	270				
	Eun negelii	239				
	Eun sp.	318				
	Fun vanberk	242				
	Eun, bilunaris v. microceph	348				
	Eun, GV	361				
	Eun. musicola	374				
	Eun. pectinalis NV	346				
	Eunotia minor	115				
	Frag brevistrata v. inflata	118				
	Frag capucina	217				
	Frag lento	117				
	Frag pinata NV	229				
	Frag pinnata v. lancetula	175				
	Frag sp	116				
	Frag vaucheriae	176				
	Frag virescens	262				
	Frust rhomb viridula	274				
	Frust mome. v. ampni Erust rhomboides	177				
	Frist vilg crass	263				
1	Frust weinholdii	302				
i,	Gomp acuminatum	120				
	Gomp afine	227		•		
	Gomp angustatum	122				'
	Gomp constriuctum v capitata 123	000			,	
	Gomp gracile	228				
	Gomp parvalum	121				
	Gomo so.	178				
	Gomp subclavicum	179				
	Gomp. GV	352				
	Gongostonium	350				
	Gryosigma spencerii	180				
	Gyro modiferum	282				
	Kinchneriella?	124				
	Klebsormidium	312				4
	Melosira distans	258				
	Melosira islandica	220				
	Melosira varians	125				
	Meridon circulare	259				
	Merismopedia	335				
	Microspora	327				
	Mougeotta Navi 2achoradan	339				
	Nav accomoda	211				
	Nav agohuohala??	317				
	Nav arvensis	133	•			
	Nav capitata	181				
	Nav celmintis	131				
	Nav cryptocephala NV	135				
7	Nav cryptocephala venter	134 .				
{ .	Nav crytoteneila	200				

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Nice, promission333Nice, promission337Odersgenium333Opphon martyi446Othoscris rosseson288Ossillatoria147Pedisistrum201PGV305Phormidium148Pitta absignation211Part absignation211Part absignation211Part absignation214Print absignation214Print absignation214Print absignation214Print absignation214Print absignation214Print absignation214Print absignation215Print discription246Print absignation217Print absignation218Print absignation218Print absignation219Print absignation219Print absignation219Print absignation219Print absignation219Print absignation210Print absignation211Print absignation212Print absignation213Print absignation213Print absignation214Print absignation214Print absignation215Print absignation216Print absignation217Print absignation218Print absignation218Print absignation218Print absignation218Print absignation219Print ab	Nice permianta 333 Odesgonium 345 Odesgonium 343 Opephora martyi 146 Oxiallatoria 147 Pediastrum 201 Party 305 Phomefalam 148 Party 305 Phomefalam 148 Party 305 Phomefalam 148 Party 263 Party 305 Phomefalam 244 Phomefalam 245 Phomefalam 245 Phomefalam 246 Phomefalam 243 Phomefalam 244 Phomefalam 245 Phomefalam 245 Phomefalam 244 Phomefalam 245 Seate abligs 2		Nitz obstues	307				
Nordurin377Nordurin316Obsysia333Opsyla333Opsyla333Opsyla301PGV305Promition148Promition249Promition249Promition249Promotion248Promotion248Promotion249Promotion248Promotion248Promotion248Promotion248Promotion248Promotion248Promotion248Promotion249Promotion249Promotion253Promotion254Promotion254Promotion254Promotion254Promotion254Promotion254Promotion255Promotion256Promotion257	Notifying317Obegonium316Overyis333Opephors marvin146Otilasorin torestana288Ossillatoria147Pefiaturum201RVV305Phormidium148Pina belayicatis318Pina belayicatis318Pina belayicatis214Pina condum244Pina deryita244Pina deryita244Pina deryita244Pina deryita254Pina deryita254Pina deryita254Pina deryita254Pina deryita254Pina deryita254Pina deryita254Pina deryita254Pina mibospita254Pina mibospita254Pina nobospita254Pina spectorin254Pina spectorin254Pina deryita254Pina deryita254Pina deryita254Pina deryita254Pina deryita254Pina deryita254Pina deryita254Pina deryita254Pina deryita254Pina deryita254<		Nitz perminuta	371				
Odesgrainim 316 Opphon matryi 146 Othersenia natryi 147 Podisiatum 201 PGY 305 Phonomialium 148 Puta abuijaanis 318 Puta abuijaanis 318 Puta abuijaanis 21 Pina abuijaanis 22 Pina davijaanis 246 Pina davijaanis 246 Pina davijaanis 247 Pina davijaanis 248 Pina davijaanis 249 Pina davijaanis 249 Pina davijaanis 249 Pina abujiatis 247 Pina abujiatis 243 Pina natavjitatis 244 Pini obaniza 247 Pina abujitat 247 Pina abujitatis 248 Pini obaniza 249 Pina abuijtatis 249 Pina abuijtatis 249 Pina abuijtatis 249 Pina abuijtatis 248 Pina abuijtat	Cologonium 316 Opephora matryi 146 Optimora matryi 147 Pediatura 201 PGY 305 Phomafilium 148 Pana blanjostis 313 Patroni dium 148 Pana blanjostis 313 Pana divergenilismina 251 Pina microstauron 243 Pina microstauron 253 Pina microstauron 253 Pina microstauron 313 Pina microstauron 253		Nodularia	357				
Oorsynia 333 Opephorn martyi 146 Otthoard execona 288 Oosillatoria 147 Pediatrom 201 Port 303 Phormáloura 143 Pino basignasis 313 Prino mabasignasis 313 Prino resultation 243 Prino resultation 243 Prino marcontauron 244 Prino marcontauron	Ocrysia333Ocrysia333Octabacti rocescona288Ocsilitoria147Pediastrim201PGV303Phornitilum148Prana baujaciai318Prane caudan225Prim dectylat240Prim dectylat244Prim abrupication248Prim abrupication248Prim abrupication248Prim abrupication248Prim abrupication255Prim abrupication255Prim abrupication255Prim abrupication255Prim abrupication255Prim abrupication255Prim abrupication255Prim abrupication255Prim abrupication255Prim abrupication256Prim decrystim200Prim decrystim201Prim decrystim202Prim decrystim203Prim abrupication255Prim abrupication255Prim abrupication254Prim abrupication264Score bilgia203Score bilgia204Score bilgia203Score bilgia204Score bilgia205Statery phosecurity274Statery phosecurity274Statery phosecurity274Statery phosecurity275Statery phosecurity275Statery phosecurity276Statery phosecurity276Stat		Odeogonium	316				
Operation matryi46Orbitolar orsevena38Osillatoria147Pediatrom201PAV305Promidium148Prina baliyania318Prina baliyania211Prina davijania225Prina davijania201Prina baliyania201Prina matropolita234Prina matropolita234Prina matropolita235Prina divergenitaria201Prina matropolita238Prina matropolita239Prina divergenitaria309Prina. divergenita309Prina. divergenita309Prina. divergenita325Prina. divergenita325Prina. divergenita323Prina. balapitaka202Scen bijiga202Scen bijiga202Scen bijiga203Scen bijiga204Scen bijiga204Scendata203Start mithi233Start printi231Start printi232Start printi231<	Opephone146Obsiltatoria147Pediatatoria147Pediatatoria305Phornitikum148Pina basignatia318Pina basignatia221Pina cawafaan225Pina cawafaan234Pina cawafaan234Pina masopleta246Pina masopleta243Pina masopleta243Pina masopleta244Pina misopleta245Pina divergentarian291Pina divergenta249Pina divergenta249Seen increasultatus201Seen increasultatus203Seen increasultatus203Seen increasultatus244Seen increasultatus244Seen increasultatus246Seria discundata244Seria discundata244Seria discundata245Site finance253Site finance253Site finance253Site finance253Site finance253Site finance253Site finance25		Occystia	333				
Ordination 288 Pediatorin 201 Portatorin 201 Portatorin 201 Portatorin 201 Portatorin 201 Promisioun 148 Prino abuignain 211 Prino caudata 225 Prino feeducition 240 Prino divergentistima 231 Prino divergentistima 234 Prino microstauron 248 Prino applata 257 Prino applata 250 Prino poscart 249 Prino applata 257 Prino applata 257 Prino poscart 258 Prino poscart 259 Prino poscarta 250 Prino poscarta	Ordination188Pediatrom201PdV205Pormidium148Phas baujasis31Phas cawlas225Phas devination248Phas baujasis246Phas devination248Phas optistisma249Phan specifistisma253Phas devination248Phas optistis253Phas optistis253Phas optistis253Phan specifistisma249Phan specifististisma253Phan specifististisma253Phan specifistististic254Phan specifististic254Phan specifististic253Phan specifististic254Phan specifististic255Phan specifististic256Phan specifististic251Star phosoconivon251Star phosoconivon251Star phosoconivon251Star phosoconivon252Star phosoconivon251Star phosoconivon251Star phosoconivon251<		Opephora martyi	146				
Oedilation147PGV305Phomabius148Phan abusipasis318Phan abusipasis321Phan caudata225Phan datry Dis246Phan datry Dis248Phan abusipasis309Phan abusipasis309Phan abusipasis325Phan abusipasis327Phan abusipasis329Phan abusipasis320Scan ablight320Scan ablight321Star abusipasi321Star abusipasi321Star abusipasi321Star abusipasi321Star abusipasi321Star abusipasi321Star abusipasipasi321Star abusipasipasi321Star abusipasipasi321Star abusipasipasi321Star abusipasipasi321Star abusipasipasipasipasipasipasipasipasipasipa	Oscillatoria147PGV305Phormaldum148Pina basanii318Pina basanii221Pina cawdan225Pina daviganii210Pina macopita246Pina macopita246Pina macopita247Pina macopita248Pina macopita249Pina macopita249Pina macopita240Pina macopita240Pina macopita241Pina macopita243Pina divergenta249Pina divergenta249Pina divergenta249Pina divergenta249Pina divergenta249Pina divergenta249Pina divergenta249Pina divergenta240Scen incrasultans201Scen incrasultans203Scen incrasultans203Scen incrasultans203Scen incrasultans204Scend quadicaudata244Stati phonecentron282Stati phonecentron282Stati phonecentron283Stati phonecentron283Stati mathii283Stati mathii284Stati filmanta293Stati filmanta293Stati filmanta293Stati filmanta293Stati filmanta293Stati filmanta293Stati filmanta294Stati filmanta293Stati filmanta293S		Orthoseria roeseana	288				
Pediatrum201POV305Phormidium143Pina basijansi31Pina neaudam225Pina neaudam236Pina neavojus246Pina nicorganismima291Pina neospleta254Pina neospleta254Pina neospleta254Pina neospleta253Pina neospleta250Pina neospleta250Pina neospleta250Pina neospleta250Pina neospleta250Pina divergena309Pina. divergena309Pina. divergena325Pina. peudomicrostauron225Pina. speudomicrostauron235Pina. speudomicrostauron235Pina. divergena309Scen incrasulatus203Scen incrasulatus203Scen obliquis150Scen obliquis150Scen adiesudatu204Scen dividuita230Stauroneis kregerii281Stauroneis kregerii281Stauroneis kregerii281Stauroneis kregerii281Star sithiti205Star instruta277Suri ovata205Star instruta276Star instruta277Star instruta276Star instruta276Star instruta276Star instruta276Star instruta277Star instruta276Star instruta277 <th>Pediatrum201POV305Phormidium148Pina abaginasia318Pina taudian225Pina caudian226Pina divergentisima291Pinn microstauron248Pina neorgina291Pina neorgina291Pina neorgina243Pina neorgina249Pina neorgina309Pina. divergentisionina325Pina. divergentisionina327Pina. divergentisoritation328Pina. persoficientistauron328Pina. divergentisoritation327Pina. divergentisoritation327Pina. divergentisoritation328Pina. persoficientistauron328Pina. Dovegenti310Seen obliquis150Seen obliquis150Seen obliquis238Staur photoscentron228Staur sindatia240Stauroneis krogeni231Stauroneis krogeni231Stauroneis krogeni231Stauroneis krogeni331Stauroneis krogeni331Stauroneis krogeni332Stauroneis krogeni333Stauroneis krogeni331Star photoxya344Stri ilbertaisooili v. kut342Stri ilbertaisooili v. kut342Stri ilbertaisooili v. kut343Stri ilbertaisooili v. kut343Stri ilbertaisooili v. kut343Stri ilbertaisooili v. kut343Stri i</th> <th></th> <th>Oscillatoria</th> <th>147</th> <th></th> <th></th> <th></th> <th></th>	Pediatrum201POV305Phormidium148Pina abaginasia318Pina taudian225Pina caudian226Pina divergentisima291Pinn microstauron248Pina neorgina291Pina neorgina291Pina neorgina243Pina neorgina249Pina neorgina309Pina. divergentisionina325Pina. divergentisionina327Pina. divergentisoritation328Pina. persoficientistauron328Pina. divergentisoritation327Pina. divergentisoritation327Pina. divergentisoritation328Pina. persoficientistauron328Pina. Dovegenti310Seen obliquis150Seen obliquis150Seen obliquis238Staur photoscentron228Staur sindatia240Stauroneis krogeni231Stauroneis krogeni231Stauroneis krogeni231Stauroneis krogeni331Stauroneis krogeni331Stauroneis krogeni332Stauroneis krogeni333Stauroneis krogeni331Star photoxya344Stri ilbertaisooili v. kut342Stri ilbertaisooili v. kut342Stri ilbertaisooili v. kut343Stri ilbertaisooili v. kut343Stri ilbertaisooili v. kut343Stri ilbertaisooili v. kut343Stri i		Oscillatoria	147				
PCV 305 Pionribilum 148 Pion branii 318 Pion branii 321 Pion abaijenis 318 Pion branii 321 Pion abaijenis 321 Pion devylus 326 Pion factylus 326 Pion factylus 324 Pion mesopieta 234 Pion obseura 329 Pion aboapieta 247 Pion abagieta 240 Scen biging 202 Scen biging 202 Scen biging 203 Scen dispuist 130 Star phonecentron 221 Star phonecentron 222 Star phonecentron 223 Stri ovata 300 <th>PCV305Phomidum143Pina bravini311Pina travini221Pina curdan225Pina factypantsirina291Pina misoples244Pina nisoples243Pina nisoples249Pina subcapitati247Pina. subcapitati248Scen bijuga202Scen bijuga202Scen bijuga203Scen bijuga240Stauroneis kreperiti213Siti patali213Siti patali213Siti patali213Siti patali213Siti patali213Siti patali213Siti patali213Siti patali213Siti patali213Siti patali214Siti patali215Siti</th> <th></th> <th>Pediastrum</th> <th>201</th> <th></th> <th></th> <th></th> <th></th>	PCV305Phomidum143Pina bravini311Pina travini221Pina curdan225Pina factypantsirina291Pina misoples244Pina nisoples243Pina nisoples249Pina subcapitati247Pina. subcapitati248Scen bijuga202Scen bijuga202Scen bijuga203Scen bijuga240Stauroneis kreperiti213Siti patali213Siti patali213Siti patali213Siti patali213Siti patali213Siti patali213Siti patali213Siti patali213Siti patali213Siti patali214Siti patali215Siti		Pediastrum	201				
Phomidium 148 Pinn brainis 31 Pinn brainis 321 Pinn brainis 321 Pinn anutan 225 Pinn divergentistima 281 Pinn microstauron 248 Pinn microstauron 248 Pinn microstauron 249 Pinn microstauron 249 Pinn a microstauron 249 Pinn a microstauron 251 Pinn a microstauron 253 Pinn a foreogena 309 Pinn. Aivergena 309 Pinn. Apseudomicrostauron 325 Pinn. apseudomicrostauron 325 Pinn. apseudomicrostauron 320 Scen increaulatus 201 Scen cobiquis 150 Scen cobiquis 150 Scen cobiquis 150 Staur phonescutron 282 Stauroneis ancepa 290 Stauroneis ancepa 290 Stauroneis kregerii 281 Star patella 320 Stari anguet	Phommidium 148 Pina basiyasis 318 Pina basiyasis 221 Pina caudan 225 Pina divergentistima 291 Pina microstauron 246 Pina microstauron 248 Pina microstauron 248 Pina microstauron 248 Pina microstauron 248 Pina divergentistima 217 Pina divergentistima 219 Pina divergentistima 210 Pina divergentistima 210 Pina divergentistima 210 Pina divergentistima 211 Pina divergentistima 212 Pina divergentistima 212 Pina divergentistima 213 Pina divergentistima 214 Pina divergentistima 214 Pina divergentistima 213 Scen divertistima 213 Scen divertistima 214 Scen divertistima 214 Scen divertistima 214 Scen divertistima 215 Stauroneis aurosis 223 Staure		PGV	305				
Pinn braudi318Pinn braudi321Pinn dactylus246Pinn dicotguron248Pinn microstauron249Pinn nicrostauron249Pinn nicrostauron338Pinn nicrostauron338Pinn nicrostauron344Pinn nicrostauron353Pinn nicrostauron348Pinn abscrin374Pinn dosura309Pinn, GV338Pinn, Storginta309Pinn, Storginta309Pinn, Storginta309Pinn, Storginta309Pinn, Storginta V. subog344Pictorina??372Rico criveration325Pinn, suboginta V. subog344Pictorina?149Soen increasultatus203Soen increasultatus204Soen diguiti150Soen quadicaudata204Soen diguiti233Sauronica kregerii231Sidg basel cells152Sidg filament153Sidg filament153Sid ovata205Synalian205<	Find a begin site318Pind beami221Find couldan225Find detrylos246Pind rousdan291Pind minesopleta254Pind nesopleta249Pind a subcapitation249Pind vergenta300Pind. obseurn325Pind a subcapitation325Pind a subcapitation325Scen obligation150Scen obligation330Stauroneit a subcapitation232Stauroneit a subcapitation235Stauroneit a subcapitation330Stauroneit a subcapitation330Stauroneit a subcapitation331Stati mintation277Stati mintation276Stati mintation276Stati mintation371Stati mintation371Stati mintation371Stati mintation371Stati mintation371Stati mint		Phormidium	148				
Pino braunii221Pino caudata225Pint divergentisimma291Pino microstauron248Pino microstauron249Pino microstauron249Pino microstauron249Pino microstauron253Pino soburat290Pino, divergentisima200Pino, divergentisima201Pino, divergentisima202Pino, pseudomicrostauron225Pino, pseudomicrostauron225Pino, pseudomicrostauron225Pino, pseudomicrostauron220Scen bijuga202Scen bijuga203Scen bijuga203Scen oniquificandata204Scendennus sp.378Staur phonecentron223Staur statili283Stauroneis kregerii281Stig basal cells152Stig filament153Sur, patella330Suri incaris223Stari fincaris223Stari statili283Sturi incaris290Stri ovata205Sturi fincaris223Stari fincaris223Stari statili230Sturi incaris221Stri ovata205Sturi incaris223Stari elast152Stri ovata205Stri ovata205Stri ovata205Stri incaris221Stri incaris221Stri ovata205Syn acians<	Finn braunii221Finn acutata225Finn divergentistima291Finn a divergentistima291Finn moritorotaturon248Finn snicorotaturon249Finn snicorotaturon247Finn, divergents309Finn, divergents309Finn, divergents325Finn, speudomicrostaturon325Finn, speudomicrostaturon325Finn, speudomicrostaturon325Finn, speudomicrostaturon320Seen bijuga202Seen bijuga202Seen bijuga203Seen andicaudata204Seen andicaudata204Seen andicaudata204Seen andicaudata204Staturoneis neeps200Staturoneis kregerit281Stig filament153Stur phonecentron282Sturi phonecentron282Sturi instatu278Suri instat277Suri instat277Suri ovalis205Suri instat278Suri instat277Suri instat277Suri instat277Suri instat277Suri instat205Suriella angolicoys304Suriella angolicoys304Suri instat277Suri instat277Suri instat277Suri instat277Suri instat277Suri insta278Syrin joloca361 <td< th=""><th></th><th>Pinn abaujensis</th><th>318</th><th></th><th></th><th></th><th></th></td<>		Pinn abaujensis	318				
Pinn catachia225Pinn darcylis246Pinn darcspiteta251Pinn microstauron248Pinn obsura249Pinn subcapitan309Pinn, divergena309Pinn, divergena309Pinn, divergena318Pinn, divergena312Pinn, divergena312Pinn, subcapitata v. subog344Pinceroniarostauron325Pinn, subcapitata v. subog344Piccotinar?372Rhoc cruvata149Soen ibigga202Soen ibigga203Soen obliquita150Soen adicaudata204Seen ebliquita150Soen adicaudata204Serue phonecentron282Staur phonecentron282Staur phonecentron282Stauroneis anceps290Stauroneis kroserit281Sig filament153Sir (aguut278Suri linearis223Stari minuta277Stari ovata205Strifila pap229Strifila pap229Strifila pap229Synd utmeen or rumpen v. familaris206Synd atume or rumpen v. familaris206Synd utmeen or rumpen v. familaris206Synd atumeen or rumpen v. familaris206Synd atumeen or r	Pinn daty225Pinn divergentisinn291Pinn mesopleta254Pinn microstauron248Pinn bisura249Pinn subcapitat247Pinn anto-appitat247Pinn. GV358Pinn. Subcapitata v. subcg344Pinn. subcapitata v. subcg344Pictorinat7?372Rico envota149Scen intersultation203Scen intersultation203Scen intersultation203Scen intersultation204Scen intersultation203Scen intersultation203Scen intersultation203Scen intersultation204Scen intersultation203Scen optificandata204Stater phonecentron282Stater sultation203Stater sultation204Stater sultation204Stater sultation203Stater sultation204Stater sultation205Stater sultation20		Pinn braunii	321				
Prind divergentisima246Prinn divergentisima251Prinn microstauron248Prinn of microstauron249Prinn of microstauron251Prinn divergentisima247Prinn, divergens309Prinn, divergens309Prinn, divergens314Prinn, peudomicrostauron325Prinn, peudomicrostauron325Prinn, peudomicrostauron325Prinn, peudomicrostauron325Prinn, peudomicrostauron325Prinn, peudomicrostauron325Prinn sobaspitata v. subog344Pictorina?120Scen bijuga202Scen bijuga304Scen obliquis150Scen obliquis304Stauroneis kregerii281Stauroneis anceps290Stauroneis anceps290Stauroneis anceps290Stari rinituta277Stri invata233Suri incaris231Stig Islament151Stri invata277Stri invata278Stri rinituta277Stri ovata205Stricilla brebiooni v, kut342Stricilla brebiooni v, kut342Stri invata216Syn dia anglicovas361Syn dia anglicovas216Syn dia anglicovas216Syn dia anglicovas216Syn dia anglicovas216Syn dia anglicovas216Syn dia anglicovas216 <th>Pron divergenitation246Pinn divergenitation254Pinn collectatoron248Pinn observation249Pinn observation247Pinn observation253Pinn abservation254Pinn divergens309Pinn, divergens309Pinn, divergens325Pinn, bitter and an and an and an antipation of a state and and antipation of a state and antipation of a state and antipation of a state and and antipation of a state and and and antipation of a state and a state and and and and and and and and and and</th> <th></th> <th>Pinn caudata</th> <th>225</th> <th></th> <th></th> <th></th> <th></th>	Pron divergenitation246Pinn divergenitation254Pinn collectatoron248Pinn observation249Pinn observation247Pinn observation253Pinn abservation254Pinn divergens309Pinn, divergens309Pinn, divergens325Pinn, bitter and an and an and an antipation of a state and and antipation of a state and antipation of a state and antipation of a state and and antipation of a state and and and antipation of a state and a state and		Pinn caudata	225				
Fram divergentismm291Phan mesopleta254Pina microstauron248Pinn obseura249Pinn sybenjieta247Pinn divergens300Pinn, divergens303Pinn, divergens344Piectorins??372Rito exclusion255Pinn, subenjieta149Seen bijuga202Seen organization150Seen audicaudata204Seen divergenta378Sputina378Sputina340Stauroneia anceps290Stauroneia anceps290Stauroneia kanceps290Stauroneia kanceps290Stauroneia kanceps290Stauroneia kanceps290Stauroneia kanceps290Stauroneia kanceps290Stauroneia kanceps293Sui oyata205Sui oyata205Sui oyata205Sui oyata205Sui oyata205Sui oyata206Syn diela aphicoxyd304Syn diela bebisooni v. kut342Syn diela bebisooni v. kut342Syn diela aphicoxyd304Syn diela aphicoxyd304Syn diela aphicoxyd304Syn diela aphicoxyd	Prind interspectitistima291Pinn microstauron248Pinn obscura249Pinn subcapitat247Pinn subcapitat247Pinn, GV338Pinn, GV338Pinn, subcapitata v. subcg344Pinto structure327Pinn, subcapitata v. subcg344Pietorina??372Rhoo cruvita149Scen incresultatis203Scen incresultatis203Scen incresultatis204Scen offiquia150Scen queficiaudata204Stauroneis ancegos290Stauroneis ancegos290Stauroneis ancegos290Stauroneis ancegos290Stauroneis ancegos290Star statis233Stauroneis ancegos290Star statis230Star statis237Star ingesti281Sig issal cella152Sig filament153Star ingesti223Stari ingesti236Stari ingesti237Stari ingesti237Stari ingesti236Syringicea363Syringicea363Syringicea363Syringicea363Syringicea364Syringicea363Syringicea363Syringicea363Syringicea363Syringicea364Syringicea363Syringicea363Syringicea </th <th></th> <th>Pinn dactylus</th> <th>246</th> <th></th> <th></th> <th></th> <th></th>		Pinn dactylus	246				
rna mesopieta248Pina microstaturon249Pina na p253Pina subcepieta247Pina divergena309Pina. GV335Pin. nubcepieta V. subcepieta247Pictoria??373Pina subcepieta V. subcepieta249Pictoria??373Pictoria??373Rhoc cuvata149Seen bijuga203Seen incressitatus203Seen incressitatus204Seen diquiciaudata204Secondiquis150Seca quaficiaudata204Secanduraticiaudata204Secanduraticiaudata205Secanduraticiaudata205Secanduraticiaudata204Secanduraticiaudata205Surroneis krogerti281State rmithi283State rmithi283State ranithi283State ranithi283<	run microspicta234Pinn nisopicta248Pinn subcapitan243Pinn subcapitan247Pinn. divergens309Pinn. CV338Pinn. pseudomicrostauron325Pinn. pseudomicrostauron325Pinn subcapitat v. subog344Pictorina?372Rhoc curvata149Seen bijngs202Seen bijngs202Seen bijngs203Seen obliquin150Soca quasicoudata204Soca quasicoudata205Suuroneis kregerii211Suri rinuta277Suri angust226Suri rinuta277Suri rinuta205Suri rinuta205Suri rinuta206Syn dirina maphicova304Syn dirina maphicova304Syn duran205Syn duran205Syn duran205Syn duran206Synd una207Synd una207Synd una207Synd una207 <t< th=""><th></th><th>Pinn divergentissima</th><th>291</th><th></th><th></th><th></th><th></th></t<>		Pinn divergentissima	291				
Prime248Pinn obsurva249Pinn sp233Pinn subcapitata247Pinn. divergens309Pinn. fivergens303Pinn. subcapitata v. subog344Pictorins??372Rhoc curvata149Scen biyga202Scen colliquia150Scen addicaudata204Scen doliquia150Scen colliquia378Sprutina203Staur phonecentron232Staur antihi233Stauroneis kregerii281Stig filament153Sur, patella330Suri inducti231Sturi minuta277Suri ovalis299Suri ovalis299Suri ovalis299Suri ovalis299Suri ovalis299Suri ovalis299Suri ovalis299Suri ovalis299Suri ovalis299Suri ovalis201Syndonas351Syn domas351Syn domas351Syn domas351Syn domas351Synd ourges or runpens v. familaris205Synd ourges or runp	Prink microstatisci248Pinn observ249Pinn observ233Pinn subcapitata247Pinn. divergens309Pinn. divergens309Pinn. divergens309Pinn. subcapitata v. subcg344Pietcoina??372Rhoe cruvata149Seen bijuga203Scen abiguita150Scen abiguita150Scen abiguita150Scen abiguita150Scen abiguita150Scen abiguita152Sture phonecentron282Stauroneis ancepa290Stauroneis kregerit281Stig filment153Stig filment153Suri intertis273Suri intertis273Suri ovalis279Suri ovalis279Suri ovalis279Suri ovalis279Suri ovalis279Suri ovalis279Suri ovalis279Suri ovalis279Suri ovalis279Syn adians351Syn adians351Syn adians351Syn adians351Syn adians351Syn adians351Syn adians351Syn adians361Syn adians361Syn adians361Syn adians361Syn adians361Syn adians361Syn adians361Syn adians361<		Pinn mesopleta	254				
Prime249Pinn ay233Pinn ay setudomicrostauron325Pinn. GV358Pinn. ay setudomicrostauron325Pinn. ay setudomicrostauron325Pinn. ay setudomicrostauron327Phoe cruvita149Picetorina?372Rhoc cruvita149Seen bijuga202Seen incrasulatus203Seen dividicaudata204Seen dividicaudata204Seen dividicaudata204Seen dividicaudata204Seen dividicaudata204Seen dividicaudata204Stauroneix kregerii281Sitauroneix kregerii281Sitauroneix kregerii281Sitauroneix kregerii281Sitauroneix kregerii281Suri ilmanti275Suri ilmanti276Suri ilmanti277Suri ovaliis299Suri ovata205Suriella anphioxys304Suriella probisconi v. kut342Synd ungens or rumpens v. familaris226Synd ungens or rumpens v. familaris206Synd ungens or rumpens v. familaris20	Find243Pinn sibbapitat247Pinn. divergens309Pinn. CV338Pinn. pseudomicrostauron325Pinn. pseudomicrostauron327Rhoc cruvata149Pictorina?372Rhoc cruvata149Seen bijuga202Seen eincrasultuts203Seen eincrasultuts203Seen eincrasultuts204Seen diguis150Seen eincrasultuts204Seen diguis340Sture phonecentron282Sture smibhi283Sture smibhi284Stig Basal cells152Stig Basal cells152Stig Isanent133Suri incura277Suri ovallis299Suri ovallis299Suri ovallis214Synd dumperas or tumpens v. famillaris216Synd dumperas or tumpens v. famillaris216Synd dumperas or tumpens v. famillaris206Synd dumperas or tumpens v. famillaris206Synd dumperas or tumpens v. famillaris206Sy		Pinn microstauron	248				
Future sp233Pinn subcapitata247Pinn. divergens309Pinn. avbcapitata v. subog344Pietorina??372Rhoo curvata149Scen bijuga201Scen bijuga203Scen curvata149Scen obiquis150Scen additude204Scen additude204Scen additude204Scen additude204Scen additude204Scendesmus sp.378Sprutina340Stauroneis kregeriti281Stauroneis kregeriti281Stig basal cells152Stig filament153Suri angust277Suri angust278Suri invalitis299Suri avalitis299Suri adaptione363Sympleca363Sym adiens351Sym adiens351Synd scues226Synd scues <td< th=""><th>Fun sp2.3Pinn subapilata247Pinn divergens309Pinn CV338Pinn subapilata v. subag344Pictorina??372Rhoc cruvata149Scen bijuga202Scen bijuga203Scen bijuga204Scen bigus204Scen durationa204Scen durationa204Scen durationa204Scen durationa204Scen durationa378Sprulina340Stauroneis anceps290Stauroneis kregerii281Stig Baan cells152Stig Baant153Suri ragust278Suri ragust278Suri ragust277Suri rotalis205Suri rotalis209Suri rotalis209Suri rotalis278Suri rotalis279Suri rotalis277Suri rotalis278Suri rotalis279Suri rotalis279Suri rotalis279Suri rotalis279Suri rotalis279Suri rotalis276Synd dura cella310Synd acus361Synd acus361Synd dura cella310Synd dura green274Tab locculosa244Tribonema341Urknown green341Urknown green341Urknown green344Wollea313<th></th><th>Pinn ooscura Ding ag</th><th>249</th><th></th><th></th><th></th><th></th></th></td<>	Fun sp2.3Pinn subapilata247Pinn divergens309Pinn CV338Pinn subapilata v. subag344Pictorina??372Rhoc cruvata149Scen bijuga202Scen bijuga203Scen bijuga204Scen bigus204Scen durationa204Scen durationa204Scen durationa204Scen durationa204Scen durationa378Sprulina340Stauroneis anceps290Stauroneis kregerii281Stig Baan cells152Stig Baant153Suri ragust278Suri ragust278Suri ragust277Suri rotalis205Suri rotalis209Suri rotalis209Suri rotalis278Suri rotalis279Suri rotalis277Suri rotalis278Suri rotalis279Suri rotalis279Suri rotalis279Suri rotalis279Suri rotalis279Suri rotalis276Synd dura cella310Synd acus361Synd acus361Synd dura cella310Synd dura green274Tab locculosa244Tribonema341Urknown green341Urknown green341Urknown green344Wollea313 <th></th> <th>Pinn ooscura Ding ag</th> <th>249</th> <th></th> <th></th> <th></th> <th></th>		Pinn ooscura Ding ag	249				
Find absolutation27Prind. GV338Prind. pseudomicrostauron325Prinn. subcapitata v. subog344Pletotina??372Rhoc cruvata149Scen bijuga202Scen bijuga203Scen obliquis150Scen obliquis204Scen dualicaudata204Stauroneis anceps290Stauroneis anceps290Suri ninuta277Suri ovallis299Suri ninuta277Suri ovallis205Suriella amphioxys304Suriella amphioxys304Synt duran205Synd aucs226Synd aucs226Synd aucs226Synd aucs226Synd aucs226Synd aucs221Synd aucs224Triboarena341Unknown green154Woltea313	Find advograda247Pina. GV338Pina. GV338Pina. pseudomicrostauron325Pina. subcapitata v. subag344Picctorina??372Rhoc curvata149Scen bijuga202Scen bijuga150Scen advisor234Scen obiquis150Scen quadicudata204Scen advisor232Statur Sinkhi233Statur Sinkhi233Statur Sinkhi231Sig basal cells152Sig basal cells152Sig basal cells153Sur oralis223Suri illinent153Suri illinentis223Suri illinentis223Suri illinentis223Suri illinentis223Suri ovallis299Suri ovallis299Suri ovallis299Suri ovallis299Suri ovallis299Suri ovallis299Suri ovallis299Syn ciella angbioxys304Syralens pi 23937Syn duna361Syn actins311Synd duna207Tab locculosa244Tribonema341Unknown green154Wollea313		Ping subaspitate	233				
Ann. GV38Pinn. pseudomicrostauron325Pinn. subcapita v. subog344Pletorina??372Rhoc envorat.149Seen bijuga202Seen iorrasultatus203Seen obliquis150Seen obliquis150Seen obliquis344Seen obliquis150Seen obliquis150Seen optimulation282Staurabonecentron282Stauroneis ancepa290Stauroneis ancepa290Staurinuta277Suri angust273Suri rivatis290Suri ovalis205Suriella amphioxys304Suriella amphioxys304Syn ndians351Syn ndians351Syn duranceata206Synd aus226Synd aus226Synd ause226Synd unanceata310Synd unanceata314Unknown green54Woltea313	Prim. GV338Prim. pseudomicrostauron325Prim. subcapitata v. subog344Pletorina??372Rhoc eruvata149Seen bijuga203Seen iorrasultatus203Secn obliquis150Seca quadicaudata204Seen domacentron282Stauroneis anceps290Stauroneis anceps290Sturi angust278Suri intariat277Suri ovalitis299Suri ovalitis299Suri ovalitis299Suri ovalitis299Suri ovalitis299Suri ovata205Symphoca363Syn redirns351Syn redirns351Syn dumapera or rumpens v. familaris226Synd unapera or rumpens v. familaris206Synd kneera201Synd kneera214Urknöwn green154Wollea313		Ping divergens	300				
Prin. pseudomicrostauron225Prin. subcapitat v. subog344Pletotina??372Rhoc eruvata149Scen bijuga202Scen incrasulatus203Scen obiquis150Scen quadicaudata204Seudicaudata204Staur smithiti283Staur smithiti283Staur smithiti283Staur smithiti283Staur smithiti281Staur smithiti283Staur smithiti283Staur smithiti283Staur smithiti283Staur smithiti283Staur smithiti283Staur smithiti283Staur smithiti283Staur smithiti284Star smithiti284Suri nacus277Suri stata205Sturi svata205Sturiella apphicxys304Suriella sponiconi v. kut342Syn exians351Syn exians351Syn exians351Syn exians351Syn exians351Syn exians363Synd sures226Synd unpens or rumpens v. familaris206Synd unpens or rumpens v. familaris206	Pinn. peudomicrostauron325Pinn. subcapitata v. subog344Piectoina??372Rhoc eruvata149Scen bijoga202Scen incrasulatus203Scen obliguini150Scen aundicaudata204Scradesmus sp.378Sprulina340Staur smithili283Stauroneis kregerini281Stig filament153Sur angust223Stauroneis kregerini281Sitig filament153Sur angust223Suri interis223Suri interis223Suri interis223Suri ovalis299Suri ovalis299Suri ovalis299Suri ovalis299Suri ovalis299Suri ovalis299Suri ovalis299Symploca363Syn radinas351Syn angust su226Synd ungens or rumpens v. familaris226Synd ungens or rumpens v. familaris206Synd ungeren211Volica311Volica311		Pinn GV	358				
Pinn. subcapitata v. subog344Pictorina??372Rhoc cirvitata149Sen bijuga202Sen incrustatus203Sea quadicaudata204Sen diarastata204Sen diarastata204Sen diarastata204Sendersmis sp.378Sputina340Staur phonecentron282Staur phonecentron282Stauroneis anceps290Stauroneis kregerii281Stig filament153Sur, patella330Suri incaris223Suri ovalis299Suri ovalis299Suri ovata205Suriella aphoxys304Suriella probioxys304Suriella probioxys304Syn poca363Syn ratinas351Syn actinas226Synd acus226Synd acus226Synd una226Synd	Pinn. subcapitata v. subog344Plectorina??372Rhoo curvata149Seen bijuga202Seen bijuga203Seen obliquia150Seen aureficaudata204Seen donkicudata204Seen donkicudata204Stauroneis anceps290Stauroneis anceps290Stauroneis anceps290Stauroneis kregerii281Sitig basil cells152Sitig filament153Suri angust278Suri innatia290Sturi rointa227Suri ovalis290Stauroneis kregerii281Sitig basil cells152Sitig filament153Suri innata277Suri ovalis290Suri ovalis290Synd unaperolati301Synd una		Pinn, pseudomicrostauron	325				
Piccorina?372Rhoo cruvata149Soen bijuga202Soen incrasulatus203Soen obliquis150Seen quadicaudata204Scendesmus sp.378Sprulina340Stur phonecentron282Stauroneis anceps290Stauroneis kregerii281Stig basal cells152Stig fiament153Suri ripatila330Suri ripatila330Suri ovalis290Stauroneis anceps290Stauroneis anceps290Stauroneis anceps290Stauroneis anceps290Suri angust278Suri innents223Suri ovalis299Suri ovalis299Suriovata205Suriella bebisconi v. kut342Sturiella pibioxys304Syn duana351Syn adiana351Syn adiana351Syn adiana205Synd umpens or tumpens v. familaris206Synd utopa363Synd utopa226Synd utopa<	Pictorina??372Rhoc eruvata149Scen ibigua202Scen incrasulatus203Scen obliquia150Scen quadicaudata204Scendesmus sp.378Sprulina340Staur smibhi283Staur smibhi281Staur smibhi281Staur smibhi283Stauroneis anceps290Stauroneis kregerii281Stig basi cells152Stig filament153Sur, patella330Suri ninetris223Suri valitis299Suri valitis299Suri valitis295Suriella brobisconi v. kut342Sturiella spitosconi v. kut342Syn actions351Syn unders226Synd acus226Synd tenera221Synd tenera221Synd tenera221Synd una207Tab Incoculosa244Tribonenna341Unknown green154Wollea313		Pinn, subcapitata y, subog	344				
Rhoc cruvata149Scen bijuga202Scen crustaltus203Scen quadicaudata204Scendusicaudata204Scendusicaudata204Scendusicaudata204Scendusicaudata204Scendusicaudata204Stauroneis anceps200Stauroneis anceps200Stauroneis kregerii281Stig filament152Stig filament330Suri angust278Suri inkearis223Suri vata205Suriella arbeitosoni v. kut342Suriella spelioxys304Synciella spelioxys304Synciella spelioxys304Synciella spelioxys304Suriella spelioxys304Suriella spelioxys304Suriella spelioxys304Suriella spelioxys304Suriella spelioxys304Synduens351Syn duchases226Synd umpers or rumpens v. familaris206Synd umpers or rumpens v. familaris206 <th>Rho cruvata149Scen bijuga202Scen incresulatus203Scen obliquis150Scen quadicudata204Scenduadicudata204Scenduadicudata204Scenduadicudata204Scenduadicudata204Staurones sp.378Sprulina340Staur phonecentron282Staur smithi283Stauroneis ancepa290Stauroneis kregerii281Stig basal cells152Stig filament153Sur, patella330Suri ringust278Suri infarearis223Suri ovaliis299Suri ovaliis205Suriella amphioxys304Suriella probisconi v. kut342Syn caliens351Syn caliens351Syn caliens351Syn caliens226Synd euron226Synd tenera221Synd tenera221Synd tenera221Synd tenera224Tirb onenna341Unknown green154Woilea313</th> <th></th> <th>Plectorina??</th> <th>372</th> <th></th> <th></th> <th></th> <th></th>	Rho cruvata149Scen bijuga202Scen incresulatus203Scen obliquis150Scen quadicudata204Scenduadicudata204Scenduadicudata204Scenduadicudata204Scenduadicudata204Staurones sp.378Sprulina340Staur phonecentron282Staur smithi283Stauroneis ancepa290Stauroneis kregerii281Stig basal cells152Stig filament153Sur, patella330Suri ringust278Suri infarearis223Suri ovaliis299Suri ovaliis205Suriella amphioxys304Suriella probisconi v. kut342Syn caliens351Syn caliens351Syn caliens351Syn caliens226Synd euron226Synd tenera221Synd tenera221Synd tenera221Synd tenera224Tirb onenna341Unknown green154Woilea313		Plectorina??	372				
Seen bijuga202Seen obijuga203Seen obijuginis150Seen quadicaudata204Seendesmus sp.378Sprulina340Staur snithili283Stauroneis anceps290Stauroneis kregerii281Stig basi cells152Stig filament153Sur, patella300Suri angust278Suri innaria299Suri orvata205Suriella brebisconi v. kut342Striella brebisconi v. kut342Syringbera363Syn patella lancolata310Syn patella lancolata311Syn patella lancolata312Syn durapens or rumpens v. famileris226Synd urapens or rumpens v. famileris226Synd urapens or rumpens v. famileris216Synd urapens214Urknown green154Wollea313	Seen bijuga202Sten incrasulatus203Sten obliquia150Seen quaficaudata204Sendesmus sp.378Sprulian340Staur phonecentron282Staur smithii283Sturroneis anceps290Sturoneis Kregerii281Sig basal cella153Sur, patela330Suri innearis223Suri innearis223Suri ovata205Surialia applioxys304Surialia applioxys304Symploca363Syn cafens351Syn cafens351Syn cafens351Syn cafens351Syn cafens351Syn cafens226Synd acus226Synd una207Tab Inocculosa244Unknown green154Wollea313	·	Rhoc cruvata	149				
Seen incrasulatus203Seen quadicaudata204Seen quadicaudata204Sendesmus sp.378Sprulina340Staur phonecentron282Staur smithii283Stauroneis kregerii281Stig filament153Sur, patella330Suri ninearis278Suri ninearis299Suri ninearis299Suri ninearis295Suri ella samphioxys304Suriella sp329Symploca363Syn radians351Syn cadheal lanceolata310Syn dumes or rumpens v. familaris226Synd uteneas221Synd uteneas221Synd uteneas221Synd uteneas221Synd uteneas231Uteneas341Unknown green154Wollea313	Seen incresulatus203Seen quadicaudata204Seen quadicaudata204Sendesmus sp.378Sprulina340Staur phonecentron282Staur smithi290Stauroneis anceps290Stauroneis kregerii281Stig basal cells153Suri angust278Suri innuta277Suri innuta277Suri ovalis299Suri ovatis299Suri ovatis299Suri ovatis299Suri ovatis299Suri angust217Suri la amphicoxys304Suriella amphicoxys304Syndians251Syndians351Syn puccata310Synd acus226Synd una207Tab flocculosa244Unknövn green154Wollea313	ſ	Scen bijuga	202				
Seen obliquis150Scen deadicaudata204Scendesmus sp.378Sputtina340Staur phonecentron282Staur smithii283Stauroneis anceps290Stauroneis kregerii281Stig basal cells152Sig filament153Sur, patella330Suri angust278Suri inearis223Suri ovallis299Suri ovallis299Suri ovallis299Suri ovallis299Suri ovallis304Suriella amphioxys304Suriella brobisconi v. kut342Striella sp363Syn nuchella lanceolata310Synd acus226Synd umpens v. familaris226Synd umpens v. familaris226Synd umpens v. familaris226Synd umpens v. familaris321Vindenen221Synd ung ceren221Synd ung ceren341Unknöwn green154Wollea313	Seen obliquis150Scen quadicaudata204Scendesmus sp.378Sprutina340Staur phonecentron282Staur smithii283Stauroneis arceps290Stauroneis kregerii281Stig basal cells152Stig filament153Sur, patella330Suri inearis223Sturi initua277Suri ovallis299Suri vorata290Suri vorata292Suri patella probiscovi v. kut342Suriella sp 3304Suri patella tanceolsta301Syn puchella lanceolsta301Syn duchella lanceolsta301Synd una206Synd una206Synd una207Tab flocculosa244Tribonema341Unknown green154Wollea313		Scen incrasulatus	203				
Scen quadicaudata204Scendesmus sp.378Sprulina340Staur phonecentron282Staur smithii283Stauroneis kregerii281Stig basi cells152Stig filament153Sur, patella330Suri rimuta277Suri incaris223Suri riminuta277Suri ovata205Suriella sphioxys304Suriella sphioxys304Suriella sponosu, kut342Syn calinas351Syn puchella lanceolata310Syn dainas351Syn dungens or rumpens v. familaris226Synd ungens or rumpens v. familaris206Synd ungens or rumpens v. familaris207Tab flocculosa244Tribonerna341Unknown green154Wollea313	Seen quadicaudata204Seendesmus sp.378Sprulina340Staur phonecentron282Staur smithili283Stauroneis anceps290Stauroneis anceps290Stauroneis anceps290Stauroneis anceps290Stauroneis anceps290Stauroneis anceps290Stauroneis anceps290Star smithili152Stig basic cells152Stig falament153Sur, patella330Sari angust278Suri linearis223Suri ovalis299Suri ovata205Suriella amphioxys304Suriella amphioxys304Suriella smithix230Syn puchtalla lanceolata310Syn cations351Syn cations226Synd una207Tab flocculosa244Unknown green154Wollea313		Scen obliquis	150				
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Wollea 313	Wollea 313		Linknown green	154				
			Wollea	313				
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Jendix IB

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Run: Relative abundance of epilithic algae for each sample Data: SLIFPERY ROCK CREEK EFILITHIC DATA 1999-2001

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Page 1 Date: 26 Feb 2002

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Original Sample Units

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Table I. Data	and Summa	ry Statisti	lcs			·			OLI	ginal Sample	A 1
Label	99FL44	99FL46	99FL60	99FL61	99FL65	99£L67		00SP44	00SP46	00FL60	
Totals	99.99	100.06	99,98	100.07	100.28	99.98	100.31	100.01	99.99	99.55	
Species ID											
100	1100.0	0.0000	0.0000	0.000	0.0112	0.0000	0.0066	0.0017	0.0000	0.0214	
102	0.0276	0.0788	0.1494.	0.1189	0.6122	0.5688	0.0729	0.0107	0.0658	0.2837	
107	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0000-07	0.0000	
109	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0563	0.0006	0.0000	0.0000	
110	0.0000	0.0000	0.0000	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0043	
111	0.0000	0.0000	0.0000	0000.0	0.0000	0,0000	0.0000	0,0000	0.0000	0.0000	
112	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0,0000	0.0000	0,0000	0.0000	
113	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0053	
115	0.0028	0.0284	0.1665	0.0067	0.0445	0.0000	0.0000	0.0023	0.0252	0.0508	
119	0.0000	÷0.0000	0.0000	0.0021	0,0000	0.0420	0.0000	0.0009	0.0000	0.0000	
120	0.0000	0.0000	0,0000	0.0010	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	
121	,0.0152	0.0047	0.0049	0.0031	0.0473	0.0056	0,0066	0.0055	0.0054	0.0187	
125	0,0000	0.0016	0.0000	0000-0	0.0000	0.0000	0.0033	0.0000	0.0000	0.0000	
127	0,0000	0.0000	0.0000	0,0000	0.0028	0000-0	0.0000	0.0006	0000000	0.0000	
128	0.0000	0.0032	0000-0	0.0000	0.0056	0.0056	0.0265	0.0017	0000-0	0.0000	
133	0.0000	0.0000	0,0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0018	0.0000	
135	0.0000	0.0000	0.0049	0,0000	0.0167	0.0056	0.1027	0.0000	0.0054	0.0000	
136	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0000-0	0.0000	0.000	
137	0.0000	0,0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0107	
139	0.0034	0.0032	0.0000	0000-0	0.0000	0.0000	0.0100	0.0009	0.0000	0.0000	
140	0.0124	0.0488	0.0147	0.0010	0.0028	0.0000	0.0232	0.0017	0.0063	0.0107	
141	0.0023	0.0126	0.0049	0.0021	0.0112	0.0168	0000 "0	0.0000	0.0018	0.0000	
142	0.0011	0.0095	0.0000	0.0010	0.0000	0.0000	0.1225	0,0023	0.0018	0.0161	
144	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0066	0.0000	0.0000	0.0000	
147	0.0000	0.0000	0.0000	0.0000	0.0000	0000.0	0,0000	0.0000	0.0067	0.0000	
: 148	0.8309	0.5271	0.2655	0.8442	0.1622	0.1315	0.0000	0.9055	0.7231	0.1838	
149	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0066	0.0000	0.0000	0.0000	
152	0.0000	0.0000	0,0000	0°0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
153	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	. 0000*0	0000 0	
154	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
160	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
162	0.0000	0.0000	0,0000	0.0000	0.0000	0,0000	0000.0	0.0000	0.0000	0.0000	
165	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
167	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0033	0.0000	0.0000	0.0000	
169	0.0000	0.0000	0.0000	0.0000	. 0.0000	0.0000	0.0033	0.0000	0.0000	0.0000	

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	00000 00000 00000 00000	0.0000	0.0000	0.0000 0.0000	0.0027	0.0000	0.0000	0.0000 0.0000	0.0000	0.0000	0.0018	0.0000	0.0000	0.0000	0.0000 0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.000	0.0000	0.0000	0.000	
	0.0006 0.0000 0.0023 0.0006	0.0020 0.0113 0.0006	0.0003	0.0000 0.0017	0.0000	0,0000	0.0000	0.0000 0.0006	0,0000	0.0000	0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000.0	0.0000	0.0000	0.0000	0.000	
	0.0000 0.0000 0.0000	0.0000 0.0000 0.0828	0.0000	0.0000 0.0000	0.0000	0,0000	0.0000	0,0000 0,0000	0.0000	0.0000	0.0100	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0,0000	0.0000	0°0000	0.0000	0.000.0	0.000	
í	0.0000 0.0000 0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.000	0.0028	0.0000	• • • • • • • • • • • • • • • • • • • •	
Υ.	00000 °0 00000 °0	0.0000 0.0000	0.0000	0.0000 0.0000	0.0000	0.0028	0.0000	0.0000 0.0000	0.0000	0.0000	0,0000	0.0028	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0,0000	0.0000	0,0000	0.0000	0,0000	0.0000	
	0.0010 0.0000 0.0005 0.0005	0.0000 0.0005 0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000 0.0000	0.0000	0,0000	0.0000	0.0000	0.0000.0	0.0000	0.0000 :	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.000	
	0.0000 0.0000 0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0000	0.0000 0.0000	0.0000	0,0000	0.0000	0,0000	0,0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	00000.0	0,0000	0000	
	0.0000 0.0000 0.0000 0.0032	0.0000 0.0189 0.0000	0.0000	0.0063 0.0000	0.0000	0.0410	0.0000	0.0000 0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.0032	0.0000	0,0000	0,000	
	0.0000 0.0000 0.0011 0.0034	0.0000 0.0288 0.0000	0.0000	0.0011 0.0006	0.0000	0.0101	0.0000	0.0001	0.0000	0.0000 0.0000	0-0017 0-0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0000	
	255 255 255 255 255 255 255 255 255 255	262 263 253	270 271	275 276	277 278	280 282	285	286 289 289	290	292 292	293 295	299	304 305	308	320 320	327	330 330	. 346	369 100	371	5/5 5/5	389	425	427	430	431	267 267	442	4 54	
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Run: Relative abundance of epilithic algae for each sample Data: SLIPPERY ROCK CREEK EFILITHIC DATA 1999-2001

Page 2 Date: 26 Feb 2002

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Original Sample Units

Table I. Data	and Summar	ry Statisti	S						Ori	ginal Sampl
Label	00SP61	00SP65	005267	00SPWC	00FL44	00FL46	00FL60 	00FL61	00FL65	00FL67
Totals	66.93	100.01	100.30	99.76	99.88	99.98	99.98	100.11	100.01	99.96
Species ID							•			
100	0.0005	0,0000	0.0000	0.0128	0.0007	0,0000	000010	0,0000	0.000	0.0000
102	0.0525	0.8700	0.5683	0.0837	0.0104	0.5614	0.1331	0.6593	0.2363	0.3367
107	00000	0,0000	0000-0	0,0000	0,0000	0.0000	0.0000	0,000	0.0000	0.0000
601 601	0,0000	0,0000	0,0000	0.0000	0,0000	0,0000	0,0000	0,000	0,0000	0,0000
III	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.0000
112	0.0310	0,0000	0.0103	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000
113	0.0000	0.0000	0.0000	0.0032	0.0000	0.0000	0000-0	0.0000	0.0000	0.0000
115	0.0086	0.0841	0.0252	0.0000	0.0039	0.0086	0.0479	0.0445	0.1003	0.0046
119	0.0000	0.0000	0.0328	0.0258	0.0000	0.0000	0.0000	0.0000	0.000	0.0077
120	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.0000	0.0129	0.0000
121	0.0005	0.0000	0.0202	0.0128	0.0023	0.0215	0.0036	0.0262	0.0939	0.0062
125	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
127	0.0000	0.0000	0.0000	0,0000	0,0000	0,0000	0.0018	0.0000	0.0000	0,0000
128	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
133	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0036	0.0000	0000-0	0.0000
135	0.0000	0.0000	0.0101	0.0096	0.0009	0.0000	0.0071	0,0000	0.0518	0.0077
136	0.0000	5 0.0000 s	0,0000	0.0000	0.0000	0,0000	0.0000	0.0000	0,0000	0000-0
137	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.0000	0.0000	0-0031
139	0,0000	0.0000	0,0000	0.0128	0.0000	0.0043	0.0071	0.0000	0.0291	0.0031
140	0.0000	0.0000	0,0051	0.0096	0.0035	0.0022	0.0000	0.0000	0.0421	0.0031
141	0.0000	0000-0	0.0000	0.0000	6000.0	0.0000	0.0036	0.0000	0.0259	0.0000
142	0.0000	0000-0	0000-0	0.0644	0.0005	0.0043	0.0000	0.0052	0.0000	0,0000
144	0.0000	0.0000	0-0000	0.000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000
147	0.0412	0.0030	0.0070	0,0000	0.0000	0,0000	0.0000	0.0000	0,0000	0000-0
143	0.6531	0.0237	0.1595	0.0070	0.9191	0.3331	0.4321	0.1418	0.0290	0.5082
149	0.0000	0,0000	0.0000	0.0290	0.0007	0.0000	0.0000	0.0709	0,0000	0,0000
152	0000 "0 "	0.0000	0.0000	0.0070	0.0000	0,0000	0.0050	0000-0	0.0000	0.0000
153	0.1941	0.0000	0.0070	0.000	0.0110	0,0000	0,0000	0.0000	0.0000	0.000
154	0.0000	0.0000	0.0000	0.0211	• 0.0000	0.0000	0.0000	00000.0	0000-0	0.0000
160	0.0000	0.0000	0000:0	0.0000	0.0002	0,0000	0.0000	0.0000	0000-0	0000 "0
162	0,0000	0,0000	0.0000	0.0000	0,0000	0.0000	0.0000	0,0000	0,0000	0.0000
165	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0300	0.0000	0,0000	0.0000
167	.0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
169	0.000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000

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		0,000 0,000000		0000 0000 0000 0000 0000 0000 0000 0000 0000
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		0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.00000 0.000000		
0.0000		0.0000 0.0128 0.0064 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000		0,0000 0,00000 0,0000 0,0000 0,0000 0,0000 0,0000 0,0000 0,0000 0,0000 0,0000 0,000000
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Page 3 Date: 26 Feb 2002

Data and Summary Statistics

Run: Relative abundance of epilithic algae for each sample Data: SLIFPERY ROCK CREEK EPILITHIC DATA 1999-2001

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Original Sample Units

Table I. Data	and Summar	ry Statisti	sol				• •		0 LI O	ginal Sample	÷
Label	OOFLWC	01SP44	01SP46	01SP60	01SP61	01SP65	01SP67	01SPWC	01FL44 	01FL46	
Totals	100.11	66 ° 66	99.95	100.01	00.66	99.93	66,66	100.03	99.96	100.01	
Species ID			• •								
100	0.0195	0.0097	0000-0	0000-0	0.0027	0.000	0.000	0,0000	0.0021	0.0000	
102	0.1267	0.1401	0.6174	0.5895	0.6039	0.3786	0.9231	0.0194	0.1028	0.7817	
107	0000-0	0.0000	0.0000	0.0000	0,0000	0.0000	0,0000	0,0000	0.0000	0,0000	
50T	0.1105	0,0097	0.0000	0,0000	0.000.0	0.0000	0,0000	0.0516	0.0000	000000	
111	0.0065	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
112	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0,0000	0.0000	
113	0.0000	0.0000	0.0000	0.0000	0000 0	0.0000	0.0000	0.0065	0.0000	0.0000	
115	0.0000	0.0538	0.0993	0.0824	0.0717	0.1119	0.0113	0.0000	0.0267	0.0087	
119	0.0000	0,0000	0,0000	0.0066	0.0000	0.0000	0.0028	0.0097	0.0000	0.0000	
120	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
121	0.0065	0.0725	0.0151	0.0264	0.0110	0.0861	0.0056	0,0000	0.0288	0.0000	
125	0.0033	0.0000	0.0000	00000.0	0.0000	00000-0	0.0000	0.0000	0.0000	0.0000	
127	0.0033	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0000.0	
128	0,0000	0.0048	0,0000	0.0000	0,0000	0000 0	0 0000	0.0000	0.0000	0.0000	
133	0.0000	0.0000	0,0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0041	0.000.0	
135	0.0098	0.0000	0000-0	0.0132	0,0000	0000.0	0.0000	0.0000	0.0041	0.0058	
136	0.0000	0.0000	0.0000	0.0000	0.0000	0000-0	0.0000	0.0000	0.0000	0.0000	
137	0.0130	0,0000	0000-0	0.0000	0.0000	0000-0	0.000	0.0129	0.0041	0.0000	
139	0.0098	0.0000	0.0060	0.0066	0.0000	0.000	0.0000	0.0000	0.0041	0.0000	
140	0.0098	0.0145	0000000	0.0000	0000.0	0.0057	0.0000	0.0839	0.0062	0.0115	
141	0.0065	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0164	0.0000	
142	0.0910	0.0193	0000-0	0.0000	0.0000	0,0000	0,0000	0.0871	0.0082	0,0000	
144	0.0000	0,0000	0,0000	0,0000	0.0000	0.0000	0.0000	0,0000	0,0000	0,0000	
147	0.0020	0,0000	0.0000	0.0000	0.0455	0.0000	0,0000	0.0000	0.0000	0.0000	
148	0.0210	0.0289	0.0938	0.0116	0.0734	0.1281	0.0010	0.0000	0.3701	0.0306	
149	0.0454	0.0193	0,0000	0.0000	0.0000	0.0000	0.0000	0.0065	0.0082	0.0000	
152	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0,0000	0.0000	0.0000	
153	10.0000	0.0000	0.0000	0.0000	0.0455	0.0000	0.000	0.0000	0.0090	0.000	
154	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0000-0	0.0000	0.0000	0.000	
160	0.0033	0.0000	0.0000	0.0000	0,0000	0.0000	0.000	0.0000	0.0021	0.0000	
162	0000.0	0,0000	0,0000	0000-0	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	
165	0,0000	0.0000	0.0000	0,0000	0.0000	0.0000	0,0000	0,0000	0.0000	0.0000	
167	0.0065	0,0000	0.0000	0,0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000.0	
169	0000.0	0,0000	0.0000	0.000	0.0000	0,0000	0.0000	0.0000	00000.0	0.0000	

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$\begin{array}{c} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 $	
$\begin{array}{c} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 $	
0.0000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.000000	
$\begin{array}{c} 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 &$	
4 4 4 4 4 4 4 4 4 7 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	
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Run: Relative abundance of epilithic algae for each sample Data: SLIFPERY ROCK CREEK EPILITHIC DATA 1999-2001

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Table I. Data and Summary Statistics

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OT FLWC	100.01	
01 FL67	100.08	
01FL65	99.93	
01FL61	101.22	
01 EL 60	66°66	
		cies ID
Label	Totals	Spec

	Species ID					
	100	0,0000	0.0420	0.0059	0.0000	0.0296
·	102	0.2497	0.3081	0.1009	0.3468	0.0493
	107	0.0000	0.0000	0.0119	0.0056	0.0131
	109	0.0000	0.0000	0.0000	0.0000	0.0325
	110	0.0000	0.0000	0.0000	0.0170	0,0000
	111	0,0000	0.0000	0.0000	0.0000	0.0296
	112	0.0000	0.0000	0:0000	0.0000	0.0000
	113	0.0000	0.0000	0.0000	0.0000	0.0131
	115	0.0416	0.0168	0.0415	0.0250	0.000
	119	0.0000	0.0000	0.0000	0.0971	0.0033
	120	0,0000	0.0056	0.0000	0.0056	0.000
	121	0.0238	0.0841	0.1336	0.0305	0.0066
	125	0.0000	0,0000	0.0059	0.0000	0.0000
	127	0.0000	0.0000	0.0000	0000-0	0.0000
	128	0.0000	0.0000	0.0000	0.0000	0.0000
	133	0.0327	0.0000	0.0000	0.0056	0.0000
	135	0.0030	0.0112	0.0534	0.0167	0.0197
	136	0.0000	0.0000	0.0000	0,0028	0.0000
	137	0.0000	0.0112	0.0000	0-0000	0.000
	139	0.0297	0.0224	0.0059	0.0056	0.2563
	140	0.0178	0.0420	0:0831	0.0222	0.0230
	141	0.0000	0,0000	0.0178	0,0000	0.0000
	142	0.0000	0.0728	0.0000	0.0000	0.1347
	144	0.0000	0.0000	0.0000	0,0000	0.0000
	1 147	0.0000	0.0128	0.0030	0 . 0000	0.0070
	148	0.0345	0.1413	0.0861	0.1499	0.0040
	149	0.0000	0.0000	0.0000	0.0000	0.0394
	152	0.0000	0.0000	0.0000	0.0000	0.0000
	153	0.0080	0.000	0,0000	0.0000	0.0000
	154	0000-0	0.0000	0.0000	0.0000	0.0000
	160	0.0000	00000.0	0.0000	0.0000	0.0033
	162	0.0000	0000 0	0.0000	0.0056	0.0033
	165	0.0000	0.0000	0-0000	0,0000	0.000
	167	0.0000	0.0000	0.0030	0.0028	0-0000
	169	0,0000	. 0.0000	0.0000	0.0000	0.0000

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Page 4 Date: 26 Feb 2002 Original Sample Units

0.0000	00000-0	0.0000	0,0000	0.000	454
0000 0	0.0000	0.0000	0.0000	0,0000	433 442
0,0000	0.0111	0.0326	0,0000	0.0000	432
0.0000	0,0000	00000	0,000	0.000	431
0.0000	0.0000	0.0000	0,0000	0,0000	430
0,0000	0.000	0.0059	0.0000	0.0000	427
0000.10	0.0028	0.0059	0.0000	0-0000	425
0.0000	0.0000	0.000	0.000	0.0000	403
0.0000	0.0056	0.0119	0.0000	0.0000	389
0.0000	0,0000	0.0000	0.0392	0.0000	5/5 076
0,0000	0.0000	0.0000	0,0000	0.0000	371
0.0394	0.0000	0.0326	0.0000	0.0000	369
0.0000	0.0000	0.0000	0.0000	0.0000	348
0.0000	0.0000	0.0000	0.0000	0.0000	346
0,0000	00000	0,000	0,000		070 030
0.0000	0.000	0.0060	0.0000	0.0240	327
0.0000	0.0000	0.0000	0.0000	0.0000	320
0.0000	0000 - 0	0.0000	0.0000	0,0000	60E
0.0000	0.0250	0.0237	0.0365	0.0208	305 205
0.000	0.0000	0,0000	0000-0	0,0000	304
0,000	0,0000	0.0059	0.0000	0.0000	9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
0.0033	0.0000	0.0000	0.0000	.0.0000	n 60 01 01
0.0000	0.0000	0.0000	0,0000	0.0000	292
0,0000	0.0000	0.0000	0.0000	0.0000	291
0000-0	0.0000	0000.0	0,000	0000-0	י אי אי
0000.0	0.0000	0.0000	0.0000	0.0000	286
0.000	0.0111	0.0504	0.000	. 0.0386	285
0.000	0.0000	0.0000	0.0028	0.0000	283
0000.0	0,000	0.0267		0,000	2 0 0 7 0 0 7 0 0
0.0000	0.0000	0.0059	0.0000	0.0000	278
0000.0	0,0000	0.0000	0.0028	0.0000	277
0.0000	0.0000	0.0000	0.0000	0.000	276
	0.0028	0,0059	0.0168	0.0000	275
0,0000	0,0000	0.0000	0.0000	0.0000	270
0.0197	0,0000	0.0000	:0.0112	0.0149	265
0.0000	0.0000	0.0000	0.0252	0.0000	263
0.000	0.0000	0.0119	0.0000	0,0000	260
0.000	0.0000	0,0000	0.0000	0.0000	259
0.000	0000 * 0 .	0.0000	0.0000	0.0000	256
0.0066	0.0000	0.0000	0.0000	0.0000	255
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Appendix IC

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Run: Relative abundance for epipelic algae 1999-2001 Data: SLIFPERY ROCK CREEK EPIPELIC DATA 1999-2001

Page 1 Date: 27 Feb 2002

Data and Summary Statistics

Table I.

Original Sample Units

Label	99FL44	99FL46	09FL60	99FL61	99FL65	99FL67	99FLWC	00SP44	00SP46	00FL60
Totals	99.98	99.95	99.97	79,92	39.95	66°66	99.98	103.09	99.95	86.98
Species ID										
100	0.0010	0.0000	0,0000	0-0040	0,0000					
102	0.0131	0-0303	0 0506		00000		2750-0	0.0097	0.0018	0.0383
107	0.0000	0,0000	0.0000		0,0000	. U.14/4	0.0161 0.0000	0.1295	0.0569	0.2107
108	0.0000	0.0000	0,0000				0,000	0.0000.0	0.0000	0.0000
109	0.0000	0.0000	0.0000	0.0000			1970'0	0.0000	0.0000	0.0000
110	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000		0.000	0,0000	0.0000
111	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000		0.000	0.0079
113	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000		0,000
115	0.0010	0.0177	0.0891	0.0085	0.0296	0.0855	0,0000	0.0078	0.0000	0.000
119	0.0000	0.0000	0.0000	0.0000	0,0000	0.0501	0.0061	0.0000	0.0000	CT01.0
120	0.0000	0.0000	0000-0	0000 "0	0.0000	0.0000	0.0000	0.0000	0.0000	00000 0
121 .	0.0044	0.0177	0.0000	0.0022	0.0473	0.0413	0.0193	0.0541	0.0207	0.0000
122	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0064	0.0000	0,0000	00000
521 525	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0225	0.0000	0.0000	0.0000
127 .	0.0000	0.0000	0.0000	0,0000	0.0000	0,0000	0.0000	0.0039	0.0000	0 0000
87T	0.0000	0.0000	0.0000	0.0013	0.0020	0.0000	0.0000	6100.0	0.0018	0000
130	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
151	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
251	0,0000	0.0000	0.0000	0.0000	0,0039	0.0118	0.0000	0.0000	0.0000	0.0055
501 101	0.000	0.0050	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000
136 120	5000 0	0.0379	0.0000	0.0018	0.0118	0.0531	0.0611	0.0058	0.0018	0.0000
127	0,000		0,0000	0,000	0.0020	0.0000	0.0000	0.0000	0.0000	0.0060
139	0.000			0.000	0.0020	0.0000	0.0129	0.0000	0.0000	0.0000
071	0.0064			6000 0	0.0039	0.0000	0.0064	0.0000	0.0018	0.0109
141	0.0000	1010 0	0.0410	8600.0	1/20.0	0.0855	0.0707	0.0097	0.0036	0.0109
1111 110			0.0000	0.000	0.0118	0.0442	0.0064	0.0000	0.0000	0.0000
4 F 7 F		0.0303	0.0000	0.0000	0.0276	0.0236	0.0354	0.0290	0.0009	0.0000
		0,000	u. uuuu	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.9276	0.2401	0.2772	0.8532	0.3992	0.1008	0.0000	0.4158	0.5211	0.0000
	0,000	0.0000	0.000	0000.0	0.0000	0.0000	0.0096	0.0000	0.0000	0,0000
		0.000	0.0000	0.0000	0.0000	0,0000	0,0000	0.0000	0-0000	0.0000
160	0.0000	0.000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0157
001 691		0.000	0.0000	0.000	0.0000	0.0000	0.0064	0.0000	0.0000	0.0000
50 T	0,000,0	0,0000	0.0000	0.0000	0.000	0.0000	0.0000	0.0000	0.0000	0.0000
) f	>>> >>		0000 °	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000

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0.0027	0.0055	0.0000	0.0000	0.0055	0.0055	0.0000	0000-0	0,0000		0.0055	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0000	0.0000	0.0000	0.0000	0.0164	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,000	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.000	0.0018	0.0063	0000-0	0.0000	0.0000	0.0036			0.0000	0.0000	0.000	0.000	0.0000	0.0000	0.0036	0.0000	0.0000	0.0036	6000.0	0.000	0.0000	0.0018	0.0000	0.0000	0.0000	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,000	0.0000	0.0000	0.2084	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	
0.000	0.0039	0.0000	0.0000	0.0232	0.0000	0.0212	0.0300	0.000	0.0058	0,0000	0 0000	0.0000	0.0000	0.0058	0.0000	0.0000	0.0039	0.000.0		0.0000	0.0039	0.0039	0,0000	0.0000	0.0000	0.0078	0.0019	0.0000	0.0000	0.0000	0.0000	0.0039		0.0000	0.0000	0.0000	0.0000	0.0039	0.0000.0	0.0019	0.0000	0.0000	0.0039	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0,0000	0.0000		0.0000	0.0257	0.0000	0.0000	0,0000	0.0000	0.0064	0.0000	0.0000	0.0032		0,000	0,000	0.0000	0.0193	0.0000	0.0000	0.0000	0.0000	0.0129	0.0000	0.0000	0.0000	0.000	0,0000		0.0000	0.0000	0.000	0.0000	0,0000	0.0225	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0064	0,0000	
0000-0	0.0000	0,0000	0.0000	0.0000	0.0000		0.0029	0.0118	0.0000	0.0000	0000:0	0.0000	0.0000	0.0059	0.0206	0.0050		0.0000	0,0029	0.0000	0.0059	0.0029	0.0000	0.0000	0.0000	0.0531	0,0000	0.0000	0,000	0,0050			0.0000	0.0000	0.0177	0.000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0,000	
0.0000	0.0039	0.0000	0.0000	0.0000	0,000	0,000	0.000	0.0000	0.0000	0.0000	0.0039	0.0000	0.0000	0.0000	0,000		0,000	0.0000	0.0000	0.0000	0.0079	0.0000	0.0039	0.0000	0.0000	0.0118	0,0000	0.0000	0.000	0.0000			0.0000	0.0000	0.0000	0.0000	0,0000	0.0039	0.0000	0.0000	0.0000	0.0000	0.0000	0.000.0		5 (nn - n	
0.0009	0.0000	0000-0	0.0000	0.000	0,000	0.0058	0.0058	0.0000	0.0000	0.0000	0.0000	0.000	0.0004	6100 0	8100.0	0,000 0	0,0000	0.0004	0.0000	0.0000	0.0000	0.01.52	0.0000	0.0000	0.0000	0.0062	0.000	0,000		0.0000	0,000	0.0000	0.0000	0.0000	0000-0	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0000-0	
0.0434	0.0000	0.0000	0.0000	0,0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.000	0.0000	0.0000	0.0000	0.0000	0.0096	0.0000	0.0000	0.0000	0.0048	0.0000	0,0000	0,0000		0.000	0,000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000.0	0.0000	0.0000	0.0000	0.0000	0.000	0,0000	0,000			
0.0000	0.0000	0.0000	0.0000		0,0000	0.0000	0.1743	0.0000	0.0050	0.0000	0.0050	0.0000	0,0000	00000	10000-0	0.0000	0.0000	0.0000	0.0000	0.0050	0.0025	0.0000	0.0000	0.0000	0,000	00000 0	0,0000	0,000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.0000	0.000	00000		0,000	0.0000	>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>	
0.0000	0.000	0,000	0.000.0	CTDD.0	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000		0.000	0.0000	0.0000	0.0000	0.0007	0.0003	0.0007	0.0000	0.0000	0,0000	0.0000	0.0000	000000	0,000	0-0000	0,0000	0,0000	0.0000	0.0000	0 - 0000	0.0003	0.0000	0.0000	0.0003	0.000	0,0000				0000	0,0000	0.0000		
251 252	502	404	200 256	で 1 1 1 1 1 1 1 1 1 1 1 1 1	260	262	263	265	270	271	275	0 . L C	978 978	280	282	283	285	289	290	291	563	295	2 N 1	102	101	308 808	909	313	316	320	329	332	335	342	347	5 F G	5 C 0 C	50 C	470	ר) מ הי ר			427	431	432		

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Run: Relative abundance for epipleic algae 1999-2001 Data: SLIPPERY ROCK CREEK EPIPELIC DATA 1999-2001

Page 2 Date: 27 Feb 2002

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Table I. Data and Summary Statistics

Original Sample Units

Label	00SP61	00SP65	00SP67	OOSPWC	00FL44	00FL46	00FL60	00FL61	00FL65	00FL67
Totals	99.96	35.95	66-66	99.97	100.76	66.99	99.98	100.04	99.98	100.02
Species ID										
001	0100 U									
102	0.00.0	0.1102	0.0000	0.0133	0.0036	0.0000	0.0000	0.0146	0.0134	0.0000
101		7011.0	1/95.U	0.0266	0.0205	0.2069	0.1412	0.1019	0.1276	0.1297
001	0.000	0.0000	0.000	0.0000	0 0000 0	0,0000	0.0000	0.0000	0.0000	0.0000
201	0.000	0.0000	0.0112	0.0000	0.0000	0,0000	0.0000	0.0000	0.000	0.0203
	0,000	0,0000	0.0000	0.0498	0.0000	0000-0	0.0000	0.0000	0.0000	0.0000
011	0.0000	0.000	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
511	0.0000	0.0000	0.0000	0.0000	0.0000	0000-0	0.0000	0.0000	0.0000	0.0000
C71	3520.0	0.1469	0.1345	0.0000	0.0018	0191.0	0.0927	0.0680	0.0672	0.0486
119	0,0000	1610.0	0.0953	0.0000	0.0000	0.0000	0.0088	0.0000	0.0000	0.2188
120	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0,0000	0.0000
121	0.0261	0.0447	0.0392	0.0033	0.0063	0.0557	0.0177	0.0680	0.0571	E000.0
T72	0.0209	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.000	0,000	0.0000
125	0.000	0.0000	0.000	0.0266	0.0000	0.0000	0.0000	0.0000	0.0067	0.0000
121	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0,000	0,000,0
128	0.0130	0.0063	0,0000	0.0199	0.0054	0.0159	0.0000	0.0000	0-0000	0000
130	0.0026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,000	
131	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2000.0	0.0000	0,000
132	0.0000	0.0063	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0 0000
133	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0 0000
135	0.0000	0.0128	0.0168	0.0199	0.0000	0.0000	0.0000	0.0000	0.0000	0.1013
136	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000
121	0,000	0.0000	0.0000	0.0133	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000
454 61	0.0182	0.0063	0.0000	0.0000	0.0000	0.0000	0.0088	0.0000	0.0000	0.0081
140	0.000	0.0543	0.0112	0.0797	0.0071	0.0796	0.0530	0.0146	0.0735	0.0892
141	0.000	0.0063	0.0112	0.0000	0.0000	0.0000	0.0309	0.0000	0.0000	0.0081
747 747	0.000	0.0063	0.0056	0.0465	0.0000	0.0000	0.0000	0.0097	0.0201	0.0162
14/	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0064	0.0000	0.0000	0.000
148	0.2044	0.0058	0.0377	0.0000	0.9098	0.1961	0.0892	0.4998	0.3001	0.0462
149	0.0000	0.0000	0.0000	0.0266	0,0000	0.0000	0.000	0.0000	0.0000	0000
150	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000
4 0 U	0.0108	0.0058	0.0189	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
163	0.0000	0.0000	0.0000	0.0133	0.000.0	0.0000	0.0000	0,0000	0.0000	0.0000
101 1	0,000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cat	0.000	0.0000	0.0000	0,0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000
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	0.0000 0.0000 0.0000	0.0000 0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0041	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0081	0.0060	0.0000	0,0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000 0.0000	0.0000	0.0000	0,000	0,0000	0.0000	0.0000	
	0.0000 0.0000 0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0067	0,0000	0.0067	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0067	0,0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0067	0.0000	0.0000	0.0000	0.0000	0.000	
	6.0000 0.0000 0.0000	0.0000	0.0097	0.0049	000000	0.0000	0.0000.0	0.0000	0.000	0.0000	0.0000	0.0000	0.0000	0.0049	6 POO . O	0.0000	0.0000	0.0000	0.0000	0.0340	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0097	0.0000	0,0000	0.0000	0.0000	0.0000)) ; ;
	0.0441 0.0000 0.0000	0.0000	0.0000	0.0000	0.0309	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0088	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
	0.0000 0.0000 0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0,0000	0.0000	0,0000 0,0080	0.0000	0.0000	0.0000	0,0000	00000	0.0159	0.0000	0,000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	00000	0.0000	
l	0.000 0.0000 0.0000	0.0018	0.0000	0.0000	00000.0	0.0009	0000.0	00000.0	0.000.0	0,0000	0.0000	0,0000	0.0000	0.0018	0.0000	0.0000	0,0000		0.0000	0.0000	0.000	00000.0	0.0000	0,0000	0.0000	0.0000	0000.0	0,0000		0.0018	0,0000	0.0000	0.0000	0.000	0.0000	0,0000	0.0000	
	0.0000 0.0000 0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0066	0.0000	0.000	0.0000	0,0000	0.0000	0.0000	0.0100	0.0000	0.0000	0.0000	0.0100	0.0000	0.0000	0000-0	0.0000	0.0000	0.0000	0.0000	0.0000	00000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0133	0.0000	
	0.0000 0.0000 0.0000	0.0000	0.0056	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0056	0.0000	0.0000	0,0000	0.0000	0.0000	0.0168	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,000	0.0000	0.0000	
	0.0000 0.0000 0.0000	0.0000	00000.0	0.0000	0.0063	0.0000	0.0128	0.0000	0,0000	0.0000	0.0000	0.0000	0,000	0.0000	0.0000	0.0063	0000	0.0000	0,0000	0 0128	0.000	0.0000	0.000.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.000	0.0000	0.0000	
	0.0000 0.0000 0.0000 0.0000	0.0026	0.0000	0.0704	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0078	0.0000	0.0000	0.0000	0.0000	0,0000	0.0104	0.0000	0.0000	0.0000	0.0000	0.0000	0.000.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.000	0,0000	0.0000	0.0000	
	251 253 254 255	256 256	260	262 263	265	270	275	276	218	280	282	283 285	583 583	290	291	100 100 100 100 100 100 100 100 100 100	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	301	304	305	806 309	313	316	02P	332 332	335	040 19	5 T T	359	369	371	573	200	203	427	431	432	
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Run: Relative abundance for epipleic algae 1999-2001 Data: SLIPPERY KOCK CREEK EPIPELIC DATA 1999-2001

Data and Summary Statistics

Table I.

Page 3 Date: 27 Feb 2002

Original Sample Units 99.99 01FL46 100.04 01 FL 4 4 100.01 -------OISPWC 100.72 01SP67 100.02 01SP65 100.001 015P61 99.99 094S10 99.97 ----01SP46 99.95 01SP44 OOFLWC 98.97 Totals Label

Spe

	0.0032	0-1132	0.0000	0.000	0.0000	0.0000	0-0000	0.0000	0.0259	0.0032	0.0000	0.0194	0,0000	0.0000	00000	0.000.0	0.0000	0.0000	0.0000	0,0000	0.0873	0.0000	010000	0.0000	0.1585	0.0000	0.0000	0.0033	0.0232	0.000	0.0000	0.000	0.0000	0.0033	0,0000
	0.0000	0.0045	0.0000	0.000	0.0000	0.0000	0.0000	0.0000	0.0011	0.0000	0.0000	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0000	0.0006	0.0006	0.0000	0.0000	0.0000	0.9713	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000
•	0.0164	0.0329	0.0000	0.0066	0.0921	0.0000	0.0099	0.0230	0.0000	0.0493	0.0000	0.0230	0.0000	0.0000	0.0000	0000-0	0.0000	0.0000	0.0000	0.0000	0.0197	0.0000	0.0164	0.0132	0.0427	0.0000	0.0756	0.0000	0.0041	0.0132	0.0000	0.0000	0.0033	0.0000	0.0000
	0.0000	0.4745	0.0000	0.0000	0.0000	0,0000	0.0000	0,0000	0.0698	0.0930	0.0000	0.0093	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0000-0	0.0279	0.0000	0.0000	0.0093	0.0326	0.0000	0,0000	0.0139	0.0417	0.0000	0.0000	0.000	0.0000	0.0139	0.0000
	0.0000	0.2325	0.0000	0.0000	0.0064	0,0000	0.0000	0.0000	0.0860	0.0414	0.0000	0.0191	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0064	0.0000	0.0000	0.0064	0.0319	0.0000	0.0255	0.0222	0.0222	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000
	0.0000	0.1500	0,0000	0000-0	0.0000	ò. 0000	0.0000	0.0000	0.0150	0.0000	0.0000	0.0450	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0100	0.0000	0,0000	0.0000	0.0000	0.0000	0.000	0.0263	0.4737	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.1350	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.1782	0.0378	0.0000	0.0108	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0000-0	0,0000	0.0054	0.0000	0.0000	0.0054	0.0081	0.0000	0.0000	0.0000	0.1519	0.0000	0.0063	0.0000	0.000	0,0000	0.0000
	0.0000	0.1424	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0271	0.0000	0000.0	0.0407	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0136	0.0000	0.0000	0.0000	0.0136	0.0000	0.0000	0.0000	0.2309	0.0000	0.0000	0,0000	0.0000	0.0000	0,000
	0,0000	0.1315	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1315	0.0000	0.0000	0,0000	0.0000	0.0000	0,0000	0,0000	0.0000	0.0057	0.0000	0000 0	0.000.0	0.0171	0,0000	0.0000	0.0357	5/35.0	0.000	0,0000	0.0000	0,0000	0.0000	0,000
	0.0389	0.0145	0.0000	0.0048	0.0730	0.0012	0.0194	0.0097	0.0000	0.0389	0.0000	0.0097	0.0000	0,0097	0.0000	0.0194	0.0000	0.0145	0.0000	0.0000	0.0827	0.0048	0,0097	0.0000	0.0486	0.0000	0,09/2	0.0025	0.008/	0.0292	0,0000	0,0000	0.034L	0,0000	0,000
ecíes ID	100	102	107	108	109	110	111	113	115	119	120	121	777	125	127	128	130	131	132	133	135	136	137	9 E T	140	141	747	7 4 7	140	149	150	154	100	191 191	C0 1

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	0.000 0.0000	0.0000 0.0000	0.0006 0.0000	0.0000 0.0000	0.0008 0.0000	0.0020 0.0194	0.0025 0.0000	0.0000 0.0000	0.0000 0 0000	0.000 0.0000	0.0000 0.0000	0.0000 0.0065	0.0000 0.0000	0.0000 0.0000	0.0006 0.0000	0.0000 0.0000	0.0000 0.0000	0.0000 0.0000	0.0000 0.0259	0.0000 0.0000	0.0000 0.0000	0.0017 0.0000	0.0000 0.0065	0.0000 0.0000	0.0000 0.0097	0.0000 0.0000	0.0000 0.0000	0.0014 0.0873	0.0000 0.0000	0.0000 0.0000	0.0000 0.0000	0.0000 0.0000	0.0000 0.0000	0.0000 0.0000	0.0000 0.0000				0.000 0.000	0.0006 0.0000	0.0000 0.0000	0.0000 0.0000	0.000 0.0000	0.0000 0.0065	0.0000 0.0000	0.0011 0.0000	
0,000	0.0000	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0263	0.0000	0.0000	0.000	0.0000	0.0263	0.0000	0,0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0066	0.0000	0.0000	0.0000	0.0000	0.0066	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0,0000		0,000	0.0041	0.0000	00000-0	0.0000	0.0000	0.0066	0.0000	0.0000	0.0066	
0-0000	0.0000	0,0000	0,0000	0.0000	0.0000	0.0047	0,0000	0.000	0.0047	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0047	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0140	0.0000	0.0000	0.0000	0.0000	0.0000	0,000		0,000	0-0000	0,0000	0,0000	0.0000	0.0000	0.0000	0.0000	0,0000	0000.0	0.0000	
0.0000	0.0000	0.0064	0.0000	0.0000	0.0064	0.0032	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0159	0.0000	0.0000	0.0000	0.0064	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0223	0.0000	0.0000	0.0000	0.000	0000-0	0,000		0.0000	0.0000	0.000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0,0000	
0,0000	0.0000	0.0000	0.0000	0.0000	0.0250	0.0000	0.0000	0000-0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0050	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	
0.0054	0,0000	0.0108	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0000-0	0.0081	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0081	0.0000	0.0000	0.0000	0,000	0.000		0.0000	0,0000	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0027	0.0000	0.0000	
0.0000	0.0000	0.0000	0.000	0.0000	0.0000	0.0000	0,0000	0.0068	0000-0	0,0000	0.0000	0,0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.000	0,0000	0.0000	0.0000	0.0000	0.0136	0.0000	0.0000	0.0000	0.0000	0.0678	0.0000	0.0000	0,0000			0000	0.0000	0.0000	0.0000	0.0000	0.0068	0.0000	0.0000	0.0000	0.0000	0.0136	0.0000	0.0000	
0000.0	0,0000	0.0057	0.0000	0.0000	0.0057	0.0343	0.0000	00000	0.0000	0.0114	0.0057	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0057	0.0000	0.0000	0.0000	0.0000	0.0000	0.0171	0,000	0.0000	0,0000			0.0000	0.0000	0.0000	0.0000	0,0000	0,0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0,000	
0.0000	0.0000	0.000	0,0000	0.0000	0.0000	0.0097	0.0000	0.0000	0.0097	0.0000	0.0000	0.0244	0.0000	0.000.0	0 0000	0.000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0097	0.0000	0.0000	0.0000	0.0000	0.0097	0.000	0.000 0.0000	0,0000		0,0000	0,0000	0.0012	0.0000	0.0000	0.0000	0.0000	0.0194	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	
251	253	254	255	256	505	200	202	203	265	270	271	275	276	277	278	280	282	283	285	269	290	291	293	295	299	105	505 205	505 505	000	202	010 316	000	329	332	335	342	347	349	359	369	371	373	388	389	10 C C C C C C C C C C C C C C C C C C C	47.4	

Run: Relative abundance for epipleic algae 1999-2001 Data: SLIPPERY ROCK CREEK EPIPELIC DATA 1999-2001

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Data and Summary Statistics Table I.

01FLWC	99.93
01FL65	99.50
01 FL61	100.05
01 FL60	99.97
Label	Totals

	0,0379	0.0063	0.0506	0.0000	0.0506	0.0000	0.0285	0.0190	0.0063	0.0221	0.0000	0.0063	0.0000	0.0664	0.0000	0.0000	0.0000	0.0000	0.0000	0.0063	0.1013	0.0000	0.0095	0.0063	0.0379	0.0063	0.0379	0.0000	0.0202	0.0379	0.0000	0.0000	0.0095	0.0040	0.0000
	0.0128	0.1945	0.0128	0.0000	0.0000	0.0000	0.0000	0.0063	0.0542	0.0446	0.0000	0.0095	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0128	0.0510	0.0000	0.0000	0,0000	0.0957	0.0000	0.0063	0.0044	0.0398	0.0032	0,0000	0.0000	0.0000	0.0000	0.0000
	0.0246	0.0663	0.0038	0.0000	0.0000	0.0000	0.0000	0.0000	0.0303	0.0000	0.0000	0.0227	0.0076	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019	0.0000	0.0000	0.0000	0.0000	0.0038	0,0000	0.0000	0.0000	0.5603	0.0000	0.0000	0.0455	0.0000	0000-0	0.0000
	0000-0	0.2338	0.0109	0.0000	0.0000	0.0000	0.0000	0.0000	0.0544	0,0000	0.0027	0.0163	0,0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0190	0,0000	0.0000	0.0000	0.0054	0.0054	0.0000	0.0190	0.1103	0,0000	0.0076	0.0000	0.0000	0.0000	0.0076
Species ID	100	102	107	108	109	110	111	511	115	119	120	121	122	125	127	128	130	131	132	133	135	136	137	139	140	141	142	147	148	149	150	154	160	163	165

Page 4 Date: 27 Feb 2002

Original Sample Units

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Appendix II

A. Taxa names and codes for macroinvertebrates

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B. Relative abundance of macroinvertebrate taxa in riffles at each site on each date.

Tricoptera	200
Hydropsychidae	203
Diplectrona	207
Hydronsyche	207
Paransyche	204
Chaumatanguaha	200
Determine	205
Polamyia	227
Macrostemum	208
Homoplectra	228
Phryganeidae	209
Phryganea	229
Agrypnia	230
Oligostomis	241
Hagenella	210
Rhyacophilidae	201
Rhyaconbila	201
Talyacophina	202
Philopotamidae	231
Dolophilodes	232
Chimarra	246
Wormaldia	771
Developed de s	A 22
Psychomidae	233
Psychomia	234
Polycentropididae	235
Neureclipsis	236
Polyantropis	242
Heliconsychidae	220
Helicopsyche	220
Molannidae	
Molanna	765
Uenoidae	237
Neophylax	238
Limnephilidae	239
Platycentropus	240
Pycnopsche	243
Chyranda	244
Psuedosteno-nhvlay	245
Apataniaidae	245
Apatanja	2.16
Apatalua	240
Goera	/53
Glossosomatidae	216
Glossosoma	217
T	A
Leptoceridae	224
Uecetis	225
Ceralcula	226
Trianenodes	297
Lepidostomatidae	218
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	Ephemerellidae	501		
	Seratella	502		
	Drunnella	504		
	Ephmerella	503		
	Eurylonhella	767		
(101		
ļ	Oligonautiidaa	600		
	Ungoneumoae	522		
	Isonychia	523		
	Polymitarcyidae	524		
	Ephoron	525		
	-			
	Ephemeridae	626		
	Ephemera	620		
	Litchronehe	527		
	Litooranciia	528		
	Hexagenia	521		
	Caenidae	515		
	Caenis 516			
	Lentophlediidae	520		
	Habrophleboides	520		
	Lantaultal	521		
	Leptophiebia	754		
	Siphlonuridae			
	Ameletus	511		
	Plecontera	600		
	Chloroperlidae	614		
	Utanerlo	C10		
	Alleperte	018		
(Anopena	615		
	Sweitsia	630		
	Peltoperlidae	607		
	Peltoperla	608		
	Perlidae 626			
	Phasganophora	620		
	Perlecta	626		
	Dorgonotino	020		
	A	632		
	Acroneuria	757		
	Capnidae			
	Allocapnia	603		
	Paracapnia	631		
	-			
	Periodidae	672		
	Clioperla	625		
	Demug	025		
	Kennus Langetai la	610		
	Leucifidae	620		
	Leuctra or Zealeutra	621		
	Isoperla	602		
	Taenioptervgidae	623		
	Taeniontervy	62.1		
	Ameonterev	U24 212		
	Ouropieryz	610		
ì	Manager			
	ivemouridae	604		
	Amphinemura	605		

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CHIRONOMIDAE GENERA:

<u>Taxon</u>	Code	<u>#</u>
Diamesinae	450	
Diamesa	451	
Pagastia	491	
Prodiamesina	452	
Prodiamesa	453	
Tanypodinae	458	
Conchapelopia	459	
Ablabesmyia	460	
Procladius	470	
Hudsonimvia	461	
Brundiniella	462	
Clinotanyous	463	
Rheopelonia	464	
Larsia	465	
Natarcia	466	
	400	
Meropelopio	407	
Maaropalopia	400	
Zauralimuio	409	
Telopologio	492	
Denteneuro	493	
Veneralenie	493	
Nilothauma	499	
Chironominos	121	
Strictochironomus	475	
Comtachironomus	470	
Missonasta	4//	
Finden birgen and	480	
Delunediliour	481	
Polypeannam Teibatan 492	482	
Theorem and a second se	101	
Riteotanytarsus	484	
Corynoneura	489	
Lanytarsus	485	
Paratanytarsus	753	
Mircotenaipes	488	
Chironomus	487	
Polypedilium fallax grp	486	
Dicrotendipes	494	
Omisis 750		
Orthocladinae	420	
Orthocladius (euorthocla	dius)	421
Orthocladius	422	
O. annectens	423	
Thienemanniella	424	
Georthocladius	425	
Parachaetocladius	426	
Diplocladius	427	
Brillia parva	428	
Brillia 429		

Appendix IIB

SRC Invertebrates fall 99- fall 01 a: SLIPPERY ROCK CREEK SURBER FALL 1999-FALL 2001

Data:

Page 1 Date: 22 Feb 2002

Original Sample Units 0-0000 0-0000 0-0000 0.0000 0.0000 0.0000 0.0080 100.00 0.0000 0.0000 0.0000 0.0000 0.0220 0.0220 0.0220 0.0220 0.0220 0.0200 0.0000 0.0000 0.0000 0.0590 0.0140 0.0000 0.0450 0.0080 0.0080 DWGSDWC 0.0000 0.0080 0.0000 0.1640 0.0150 0.0000 0,0000 0.0000 0.0000 0.0000 0.0000 100.00 0.000.0 0.0000 0.0000 00SP65 0.0000 0.0000 0.000.0 0.0000 0.0000 0.2124 0.0000 0.0601 0.0000 0.0000 99.80 0.0912 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0301 0.0000 0.0000 0.0000 0.0000 0.0301 0.0000 0.0000 194S00 0.0000 0.0000 0.0000 0.0301 0.0301 0.000.0 0.0301 0.1824 0.000.0 0.0000 0.0000 0.0000 0.0000 99.90 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0,0000 0.0000 0.0000 0.0000 0.0000 0.0000 00SP46 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.3333 0.0000 0.0000 99.90 0.0000 0,0000 0,0000 0,0000 0,0000 0,0000 0,0000 0,0000 0,0000 0,0000 0.0000 0.0000 0.0000 0.0000 00SP44 0.000.0 0.0000 0.0000 0.0000 0.0000.0 0.0000 0.0000 0.0000 0.0000 0.000.0 0.0318 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 100.50 0.0149 0.0000 0.0060 0.0318 0.0418 0.0000 0.0000 0.0000 0.0000 0.0109 0, 0000 0, 0060 0, 0000 0.0000 0.3950 99 FLWC 0.0000 0.0000 0.0109 0.0000 0.0478 0.0000 0.000.0 0.0060 0.0000 •• 0.0000 -----99.90 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.1111 0.1111 99*E*L65 0.0000 0.3333 0.0000 0-0000 0.0000 0.0000 0.0000 0000-0 0.1111 0.0000 0.0000 0.2222 0.0000 0.0000.0 0.0000 0.0000 98.50 0.0000 0.0000 0.0000 0.0000 0.0558 0.0112 0,0000 0,0112 0,0000 0,0000 0.0112 0.0112 0.0000 0.0223 0.0000 0.0223 0000-0 0.0000 **191366** 0.0670 0, 0000 0, 0000 0.0000 0.0782 0.1107 0.0223 0.0000 0-0000 0.0000 0.0000 0.0558 Data and Summary Statistics 100.00 0.0000 0.0000 0.0000 0.2000 0.000.0 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.000.0 0.0000 0.0000 0.0000 0.000.0 0.0000 0.0000 0,0000 99FL46 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 100.00 0.0000 0.0000 0.0000 0.1660 0-0000 0.0000 0.0000 0.1670 0.0000 00000.0 0.0000 0.0000 0.0000 0.0000 99EL44 0.0000 0.000.0 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.000.0 0.1670 0.0000 Species ID 402 405 \$07 123 123 ц. Tctals Table Label

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Run: SRC Invertebrates fall 99- fall 01 Data: SLIPPERY ROCK CREEK SURBER FALL 1999-FALL 2001

Table I. Data and Summary Statistics

Original Sample Units

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				••					•	
Label	00FL44	00FL61	00FL65	00FLWC	01SP44	01SP61	01SPWC	01FL44	015160	01FL61
Totals .	06*66	100.10	100.10	100.30	08.80	08.80	100.70	99.70	100.20	99.70
Species ID					·					
102	0,0000	0.0000	0000-0	0.0419	0.0000	0.0000	0.0745	0.0451	0.0000	00000
103	0.0000	0.0190	0-0000	0.0000	0,0000	0.1433	0.0000	0.0451	0.0000	0.0572
104	0.0000	0.0869	0.0000	0.0000	0.2144	0 0000	0.0000	0.1364	0.0000	0.2738
105	0.1111	0.0050	0.0000	0.0000	0.0000	0-0000	00000.0	0.0000	0.0000	0.0000
011	0.0000	0.0000	0.0649	0.0050	0.0000	0000.0	0.0000	0,0000	0.0200	0.0000
113	0.1111	0.0100	0-0000	0.0000	0000 0	0.0000	0.0000	0.1361	0.0000	0.0341
115	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0451	0000000	0.0000
117	0.0000	0.0000	0.0000	0,0000	0,0000	0,0000	0.0129	0,0000	0.0000	0.0000
121	00000	0.0000	0.0000	0.0000	0.2144	0.0000	0,0000	0.0000	0000-0	0.0000
122	0.0000	0.0000	0.0649	0.0000	0.0000	0000.0	0.0377	0,0000	0.0000	0.0000
202	0,0000	0.0430	0.0320	0.0030	0.0711	0.0711	0,0000	0.0000	0.0200	0110.0
204	0.1111	0.000	0.0000	0.2512	0.0000	0.0000	0.1241	0.0000	0.1567	0.0000
205	0.0000	0.0140	0.3546	0.1735	0.0000	0.0711	0.1490	0.1364	0.7236	0.1023
232	0.0000	0.000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0-0000	0.0231
243	0.0000	0,0000	0.0000	0.0000	0.1433	0.0711	0.0129	0.0000	0.0200	0.0000
246	0.0000	0.0000	0.0320	0.0000	0.0000	0.0000	0.0000	0.000.0	0.0200	0.0000
301	0.1111	0,-0000	0.0000	0.0030	0.0000	0.0000	0000-0	0.0000	0-0000	0.0110
302	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0.0377	0.0000	0.0000	0.0000
303	0.0000	0.1838	0.0649	0.0080	0.0000	0.0000	0.0129	0,0000	0,0000	0.0231
306	0.0000	0.0000	0.0000	0.0030	0.0000	0.0000	0,0000	0.0000	0.0000	0000.0
307	0.0000	0.0050	0 0 0 0 0 0 0	0,0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0110
310	0.0000	0.0000	0.0000	0.0698	0.0000	0.0000	0.2860	0,0000	0.0000	0.0000
402	0.0000	0.0140	0,0000	0.0000	0.1433	0.1433	0.0000	0,0000	0,0000	0.0682
405	0.0000	0.0000	0.0000	0,0000	0.0000	0.0000	0,0000	0.0913	0.0000	0.0110
408	0.0000	0.0000	0.0000	0.0030	0.0000	0,0000	0,0000	0.0000	0.0000	0.0000
426	0.0000	0.0050	0.0000	0.0000	0.0000	00000-0	0,0000	0.0000	0.0000	0.0000
430	0.0000	0.0050	0.0000	0,0000	0.0000	0.0000	0000-0	0,0000	0.0000	0.0000
431	0.0000	0.0000	0.0000	0.0000	0.0000	0,0000	0.0000	0.1825	0.0000	0.0000
432	0.1111	0.2418	0.1608	0.0000	000000	0,0000	0,0000	0,0000	0.0000	0.0913
433	0.3333	0,0000	0,0000	0.0419	0,0000	0.0000	0000-0	0.0000	0.0000	0.0000
435	0.0000	0000 0	0.0000	0.0419	0.0000	0.0000	0.0129	0 0000	0,0000	0.0000
461	1111.0	0.0050	0.0000	0.0000	0.0000	0,0000	0.0000	0,0000	0.0000	0.0000
465	0000 0	0.0050	0,0000	0.0000	0,0000	0.0000	0.0000	0.0000	0.0000	0.0231
480	0000.0	0.0050	0.0000	0.0000	0.0000	0.0000	0,0000	0.0451	0000-0	0.0000

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Page 2 Date: 22 Feb 2002

0.6512 0.6220 0.6728 0.4803 0.9142 0.9032 0.6816 0.6466 0.9106 0.8961 0.9106 0.8961 0.7374 0.7064 0.7158 . 0.6732 0.6593 0.6251 0.8653 0.8397 . . N(2)/N(1) N(2)-1/N(1)-1

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Hill's Numbers

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22.0000	6.2684	3.7430		0.2849	0.5971	0.5206
10.0000	5.9343	3.7308		0.5934	0.6287	0.5534
(0)N	N(1)	N(2)	Hill's Ratios	(0)N/(T)N	N(2)/N(1)	I-(1)N/I-(2)N

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

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Received 12 September 2001; accepted 28 December 2001

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

Abstract

23 Restoration of streams impacted by acid mine drainage (AMD) focuses on improving water quality, however precipitates of 24 metals on the substrata can remain and adversely affect the benthos. To examine the effects of AMD precipitates independently 25 of aqueous effects, four substrata treatments, clean sandstone, clean limestone, AMD precipitate-coated sandstone and coated 28 limestone, were placed in a circumneutral stream of high water quality for 4 weeks. Iron and Al were the most abundant metals on 27 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 cad-28 disflies was significantly lower when exposed in situ for 5 days in an AMD affected stream than in a reference stream. Caddisfly 29 whole-body concentrations of all combined metals and Fe alone were significantly higher in the AMD stream. Whole-body metal 30 concentrations were higher in killed caddisflies than in live, indicating the importance of passive uptake. The results suggest the 31 aqueous chemical environment of AMD had a greater affect on organisms than a coating of recent AMD precipitate on the sub-32 strata (ca. 0.5 mm thick), and treatment that improves water quality in AMD impacted streams has the potential to aid in recovery 33 of the abiotic and biotic benthic environment. © 2002 Published by Elsevier Science Ltd. 34

37 1. Introduction

Acid mine drainage (AMD) from abandoned coal 39 40 mines degrades more than 12,000 km of streams in the Appalachian Region of the Northeastern, USA, with 41 80% of the impacted stream miles located in western 42 Pennsylvania and West Virginia (USEPA, 1997). The 43 estimated cost of reclamation of watersheds affected by 44 AMD in Pennsylvania is over \$15 billion (Rossman et 45 al., 1997). Acid mine drainage occurs when pyrite and 46 other sulfide minerals associated with coal seams are 47 exposed to water and oxygen. A series of chemical 48 reactions results in mine water discharges that can be 49 high in acidity and concentrations of metals. High 50 acidity results from the oxidation and/or hydrolysis of 51 Fe and other metals. At pH values of 2-3 in aerobic 52 environments, acidophilic bacteria are the primary 53 54

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oxidizers of Fe, which then hydrolyzes and precipitates 93 out of solution in copious amounts. At pH > 5, the 94 abiotic oxidation of Fe⁺² predominates. Ferric iron 95 ions produced by the oxidation of pyrite are capable of 98 dissolving other heavy metal minerals, which enter into 97 solution at low pH (Singer and Stumm, 1970; Hedin et 98 al., 1994; Mills and Robertson, 1995). When AMD runs 99 off into more alkaline conditions in streams, dissolved 100 metals such as Al, Zn, Cu and Pb precipitate, however 101 these reactions are often out of equilibrium. Physical 102 and chemical conditions in the sediment, and hydrol-103 ogy, also affect metal speciation and transport down-104 stream (Boult et al., 1994; Broshears et al., 1996). 105

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

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D.M. DeNicola, M.G. Stapleton | Environmental Pollution [] ([]]]) []-[]

Table 1

General chemical and biological parameters at the two stream sites used for experiments in the study, Slippery Rock Creek (at AMD impacted 2 Station 65) and Wolf Creek (unimpacted reference stream)*

Parameter	Slippery Rock Creek	Wolf Creek
Discharge (m ³ s ⁻¹)	0.1–3.5	0.4-6.7
Width at low flow (m)	4.3	6.7
pH	6.3 (5.5-6.6)	7.7 (6.5-8.1)
Alkalinity (mg CaCO3 1 ⁻¹)	11.7 (4.1-40.0)	76.2 (24.9-149.9)
Acidity (mg CaCO ₃ 1 ⁻¹)	8.3 (3.4-13.6)	2.5 (0-8.3)
Sulfate (mg l ⁻¹)	255 (245-260)	70 (60-79)
Soluble Fe (mg 1 ⁻¹)	0.40 (0.20-1.88) ^b	0.04 (bd°-0.19)
Soluble Mn (mg 1 ⁻¹)	4.10 (bd-9.50)°	0.08 (bd-0.1)
Soluble AI (mg l ⁻¹)	0.10 (bd-0.55)° 5	0.14 (bd-0.40)° 5
Soluble Zn (mg i ⁻¹)	0.07 (bd-0.12)°},	0.04 (bd-0.10)
Sediment Fe (g kg ⁻¹)	51.0 (20.6-99.0)	44.9 (13.7-114.9)
Sediment Mn (g kg ⁻¹)	4.1 (0.4–16.4)	0.8 (0.3-6.7)
Sediment Al (g kg ⁻¹)	27.9 (23.8-30.5)	37.0 (27.3-63.2)
Sediment Zn (g kg ⁻¹)	0.3 (0.1-1.2)	0.2 (0.2-0.7)
Macroinvertebrate density (number m ⁻¹)	4 (054)	897 (369-1764)
Marcoinvertebrate species richness	2 (0-6)	27 (15-34)
Epilithic periphyton density (number cm ⁻¹)	1.7×10 ⁵ (2.2×10 ⁵ -6.9×10 ⁵)	1.2×10 ⁶ (1.1×10 ⁵ -1.2×10 ⁷)
Bpilithic periphyton species richness	21 (14-31)	23 (18-37)

* Values are medians and ranges based on quarterly sampling from 1995 to 2000. Sediment concentrations are for the clay fraction of sediment. ^b Concentration of maximum dissolved metal exceeds either USEPA's or Pennsylvania's continuous water quality standard for freshwater.

^c Below detection limits.

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order tributary of Slippery Rock Creek and of good 25 water quality (Table 1). It is approximately 30 km 26 downstream of the headwater area and drains a mix of 27 woodland and agricultural areas. 28

3. Materials and methods 31

33 3.1. Substratum experiment

To examine the effects of AMD precipitate on epi-35 lithic invertebrates and periphyton, 30.5×30.5×4.0 cm 36 wooden frames with 1.0 cm² open mesh, plastic bottoms 37 were filled with cobble-sized substrata obtained from a 38 39 quarry. To obtain substratum treatments with an AMD 40 coating, frames filled with either sandstone or limestone cobble were placed in a highly impacted, untreated 2nd 41 42 order AMD stream in the headwaters of Slippery Rock 43 Creek for 3 weeks to accumulate a precipitate coating 44 approximately 0.5 mm thick (estimated visually by 45 scraping the substratum). This stream contains few to no macroinvertebrates and a visual inspection of the 48 47 cobbles in the trays indicated no invertebrates were 48 present after the 3-week exposure. These trays were then transferred in water-filled containers to a circumneutral 49 stream with good water quality, Wolf Creek, on 13 50 51 October 1998. On the same date, substratum trays con-52 taining either clean, washed limestone or clean, washed sandstone treatments were also placed in Wolf Creek. 53 Five replicates of the four substratum treatments, clean 54 (control) sandstone, clean (control) limestone, AMD 55 58 coated sandstone and AMD coated limestone, were

located randomly in a long riffle of the stream for a 4-81 week exposure. Metals were sampled from the substratum in the trays before and after being placed in 83 Wolf Creek. Substratum in the trays were sampled for 84 macroinvertebrates and periphyton at the end of the 4-85 week exposure. 88

To examine changes in metal concentrations on the 87 substrata during the 4-week exposure, randomly selec-88 ted cobbles from trays of each treatment (n=5) were 89 analyzed for metals before and after being placed into 90 Wolf Creek. The entire surface of each rock was scrub-91 bed with a hard bristle, plastic-brush using a 2% HNO₃ 92 solution. Material scrubbed and rinsed from the cobble 93 was digested for metal analyses using nitric acid (diges-94 tion procedure 303E, APHA, 1998). Concentrations of 95 Al, Fe, Mn, and Zn were determined using a Perkin 96 Elmer Plasma 400, inductively coupled plasma spectro-97 photometer (ICP; preliminary studies have shown these 98 to be the most abundant metals). Accuracy and preci-99 sion of metal analyses were determined by running 100 duplicates, blanks, standards and spiked samples at a 101 frequency of approximately 1 per 10 normal samples. 102 Samples outside of limits of acceptability (10%) were 103 rerun (APHA, 1998). 104

Invertebrates from each tray were sampled by placing 105 a 500-µm mesh net directly downstream of the tray and 106 rubbing invertebrates off each cobble by hand into the 107 net. Invertebrate samples were preserved in 70% etha-108 nol and individuals identified to genus using primarily 109 Peckarsky et al. (1984). Prior to invertebrate sampling, 110 one randomly selected cobble was taken from three of 111 the five trays for each treatment to sample periphyton 112

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D.M. DeNicola, M.G. Stapleton | Environmental Pollution [] ([]]]

significant interaction between substrata treatment and 1 2 change in concentrations during the 4-week exposure in Wolf Creek (Fig. 1A). Iron concentration did not change 3 significantly on either the sandstone or limestone control 4 5 substrata but significantly decreased on both AMD sub-6 strata. Aluminum concentrations were significantly different among substrata treatments and were higher on 7 AMD sandstone than control sandstone substrata. 8 9 There was a significant interaction between substrata treatment and the changes in Al concentrations, with 10 all treatments losing aluminum during the exposure 11 except sandstone control (Fig. 1B). Concentrations of 12 manganese and zinc on the rocks were quite a bit lower 13 than for Fe and Al, with all values less than 0.01 mg 14 cm⁻². Changes in Mn concentrations on the rocks were 15 also significantly affected by the substrata treatment. 16 Unlike the other metals, control substrata treatments 17 significantly gained Mn during the experiment, but there 18 was not a significant increase on the AMD treatments 19 20

which had higher initial Mn concentrations (Fig. 1C), Zinc concentrations on the substrata were relatively low, and there were no significant main affects of treatments or change during exposure. Although there was a significant interaction between substrata type and concentrations of Zn before and after exposure, there were no consistent trends in the changes (Fig. 1D).

After the 4-week exposure in Wolf Creek, mean 64 macroinvertebrate densities were not significantly dif-65 ferent among substrata treatments, although they were 66 slightly higher on control treatments (Fig. 2). Shannon 87 diversity values for macroinvertebrates varied from 1.0 88 to 1.4 and were not significantly different among treat-69 ments (Table 2). Taxonomic composition of the macro-70 invertebrates on the four substrata treatments was 71 similar, with the stonefly, Taeniopteryx sp., and the 72 mayfly, Isonychia sp., dominating the assemblages. Each 73 of the five most abundant macroinvertebrate taxa did 74 not differ significantly in their relative abundance 75



Fig. 1. Mean concentrations of Fe, Mn, Al and Zn on four substrata treatments before and after exposure in an unimpacted reference stream, Wolf Creek. Asterisks indicate a significant change (P < 0.05) in concentration during the exposure within each treatment. Error bars are 1 SE, n = 5. Ss, sandstone, Ls, limestone. $\Delta PO = 2 + i + i$

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Periphyton assemblages as a whole were not significantly different among treatments based on the CCA
permutation test.

52 4.2. Aqueous exposure of caddisflies

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During the 5-day caddisfly exposure, Wolf Creek had a higher pH and alkalinity, and was lower in the conductivity and acidity than the AMD affected site in Slippery Rock Creek. Temperature at the two sites was about the same and dissolved oxygen was slightly higher in Wolf Creek (Table 4). Concentrations of Fe and Mn dissolved in the water and in the seston were one to two orders of magnitude higher at the Slippery Rock Creek site than in Wolf Creek, but concentrations were only slightly higher for Zn, Pb, and Cd (Table 5).

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In Wolf Creek, 91.4% (SE = 3.4) of the caddisflies in 111 the live treatment survived during the 5-day exposure, 112



Fig. 4. Mean whole-body concentrations of Fe, Al, Mn, Zn, Cd and combined metals for live and dead hydropsychid caddisflies after a 5-day exposure in Slippery Rock Creek (at AMD impacted Station 65) and Wolf Creek (unimpacted reference stream). Error bars are 1 SE, n=7, bd, below detection limits. Asterisks indicate a significant difference (P < 0.05) in concentration between live and dead caddisflies within a stream site, or between stream sites for all caddisflies.

rather than physical abrasion from the current. Con-48 centrations of Zn and Mn on the substrata were 1-2 47 orders of magnitude lower than Fe and Al. Under oxi-48 49 dizing conditions, precipitation of Mn is much greater at pH > 6 (Hedin et al., 1994) and thus more likely in Wolf 50 51 Creek than the AMD site, however aqueous concentrations in Wolf Creek were very low. It is likely changes in 52 the concentration of Zn and Mn after exposure in Wolf 53 Creek may have been relatively more affected by forma-54 tion of a biofilm containing these elements than by 55 changes in mineral solubility or adsorption. 56

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After the 4-week exposure in Wolf Creek, there were 102 no significant differences between AMD coated and 103 control substrata in abundance or taxonomic composi-104 tion of invertebrates or periphyton. Several aquatic 105 invertebrates have been shown to be tolerant of high to 106 moderate levels of dissolved Fe (Rasmusssen and Linde-107 gaard, 1988; Gerhart, 1992; Rousch et al., 1997). How-108 ever, studies of mine drainage in which stream pH values 109 are circumneutral and dissolved metals low, have sug-110 gested that loose, unattached precipitates of ferric iron 111 hydroxides can have devastating affects on invertebrate 112

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D.M. DeNicola, M.G. Stapleton / Environmental Pollution [] (

when uptake exceeds the organisms ability to regulate 1 the metal or bind it in a nonlethal form (Hare, 1992; 2 Gerhart, 1993). While the pH of Slippery Rock Creek 3 during the exposure was over 6.0, it was lower than the 4 pH of Wolf Creek and it was likely to have a greater 5 concentrations of more toxic, free-ion forms of the 8 metals (Table 1). Caged caddisflies in the AMD impac-7 ted stream had significantly higher concentrations of 8 most of the measured metals, with concentrations of Fe 9 and Al being the highest. Most aquatic animals regulate 10 Fe well and LC50 values for dissolved Fe are relatively 11 high (3-300 mg l⁻¹; Gerhart, 1993, 1994). Precipitation 12 of Fe hydroxides can decrease survival because of dis-13 ruption of intestine membranes, clogging of the diges-14 tive tract, and coating of gill surfaces (Gerhart, 1992, 15 1993). Although no visible orange precipitate was seen 16 on the caddisflies placed in the AMD site, precipitate 17 formed on the cages in that stream indicating that some 18 precipitation of Fe on the organisms was more likely 19 than in Wolf Creek. Toxicity of Al on aquatic insects 20 appears to result mainly from affects on gills and 21 respiration (Rosenberg and Resh, 1993). While dis-22 solved ionic Al can disrupt ion transport across gill 23 membranes, respiration can be also affected in part by 24 precipitation of Al hydroxide on gill surfaces. Krantz-25 berg and Stokes (1988) found maximum Al body bur-28 27 dens of chironomids were greatest between pH 5.1 and 5.6, a level close to the pH at our AMD site. 28

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29 Comparison of whole-body concentrations in live vs. dead caddisflies implies that although active ingestion of 30 31 metals can lead to toxic internal affects, passive uptake of metals on external body surfaces also can be an 32 33 important uptake mechanism in hydropsychid caddis-34 flies, which may lead to chronic lethal affects associated with gills or sensitive surfaces. It was surprising that 35 36 dead caddisflies had higher total body concentrations 37 than live for all metals, as most studies find little differ-38 ence in metal uptake between live and dead aquatic insects (Timmermans et al., 1992). Iron in the gut con-39 tents of hydropsychid caddisflies make up 34-60% of 40 41 the Fe in the whole body (Smock, 1983; Cain et al., 1995), and we assumed active uptake of filtered seston 42 would increase metal concentrations in live organisms in 43 the AMD stream. Dead caddisflies were depurate and 44 their mass was about half that of live, thus it appears 45 that metals associated with passive surface sorption 46 increased the whole-body concentrations in dead 47 organisms. Other factors that could increase the con-48 centration of metals in dead vs. live caddisflies are the 49 release metals sequestered in granules near the body 50 surface after death (Krantzberg and Stokes, 1988), the 51 release of proteins in killed organisms that then adsorb 52 metals from solution (Timmermans et al., 1992), the 53 lack of metal regulation/excretion in dead organisms, 54 and the possibility that metals precipitated on the 55 retreats and nets of live hydropsychid caddisflies, rather 56

than on the body surface (Letterman and Mitsch, 1978; Brown, 1977).

6. Conclusions

62 Understanding the relative roles of substratum and 63 aqueous chemical affects of AMD on benthic organisms 84 is critical to successful remediation of impacted streams. 65 The building of passive systems to treat coal mine dis-66 charges entering streams has increased substantially in 67 the past 5 years (Milavec, 2000; Rossman et al., 1997), 68 but there has been little examination of the relative 69 roles of the benthic vs. aqueous environment on the 70 recovery of stream benthos. Results from this study 71 indicate that aqueous AMD chemical environment in 72 Slippery Rock Creek had a greater affect on organisms 73 than the chemical precipitate on substrata. Hard sub-74 strata coated with AMD precipitate had a significant 75 decrease in the most abundant metals, Fe and Al, and a 78 benthic flora and fauna similar to control substrata when 77 placed into an unimpacted aqueous environment, 78 whereas caddisflies exposed to a moderately impacted 79 aqueous AMD environment had significantly higher 80 mortality and metal concentrations in their bodies. 81 While treatment of several large AMD inputs into Slip-82 pery Rock Creek have improved the overall aqueous 83 environment, water chemistry appears to continue to 84 limit the recovery of benthic organisms. Increased AMD 85 discharge during storm events can overwhelm or bypass 86 treatment systems, and the temporary deterioration in 87 stream water quality can increase the negative impact on 88 benthic organisms (Verb and Vis, 2000; DeNicola and 89 Stapleton, 1999). Moreover, decades of accumulated 90 AMD precipitate deposited on the substratum may now 91 be out of equilibrium with the treated aqueous environ-92 ment, and thus be a source of aqueous metals. Our study 93 suggests improvement in water quality resulting from 94 passive treatment systems should aid in the recovery of 95 the chemical and biological environment of the substrata 98 in AMD affected streams. While AMD affected sub-97 strata recovered quickly in our transplant experiment, 98 the cobble was coated with a thin, recently deposited 99 precipitate, which is most representative of riffle areas 100 where flocculent precipitates do not accumulate. Sec-101 tions of other streams and Slippery Rock Creek that 102 have accumulated layers of encrusted and flocculent 103 AMD precipitate may take substantially longer to 104 recover given improved water quality. 105

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