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
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

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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.

TIMELI' ˢELECTED EVENTS

Date	From	To	Description
1996/07/25	CDS	PADER, BLWC	FY98 EPA Funding Request
1996/10/16	PADER, BLWC	CDS	FY98 EPA Funding Approval
1996/11/12			Harrisburg meeting with NPS staff
1997/04/11	CDS	PADEP, BWC	Quality Assurance Work Plan
1997/11/01	PADEP, BWC	CDS	ME# 358079 contract
1998/04/28	CDS	PADEP, BWC	Grant transfer request from CDS to SRI
1998/06/23	PADEP, BWC	SRI	Receipt of revised agreements for execution
1998/07/13	SRI	PADEP, BWC	Revised executed agreements
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/[illegible]	Aquascape	PHMC	Notification
2000/10/[illegible]	BMI	McKay&Gould	install piezometers [illegible]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

2001/12/	SRI	Quality Aggregates	order limestone ag gate (AASHTO #1, 57, R4)
2001/12/	SRI	Interstate Pipe	order pipe, fittings,
2001/12/20	Citizens Bank	SRI	$10,000 cashier's check for road bond
2001/12/26	PennDot	SRI	Temporary 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.

(l-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.

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

Goff Station (2001)
Four Vertical Flow Systems
Acid Removed: 7,258 lbs/mo
Fe Removed: 417 lbs/mo
Al Removed: 367 lbs/mo
Bat Hibernaculum
Naturally-Functioning Wetlands

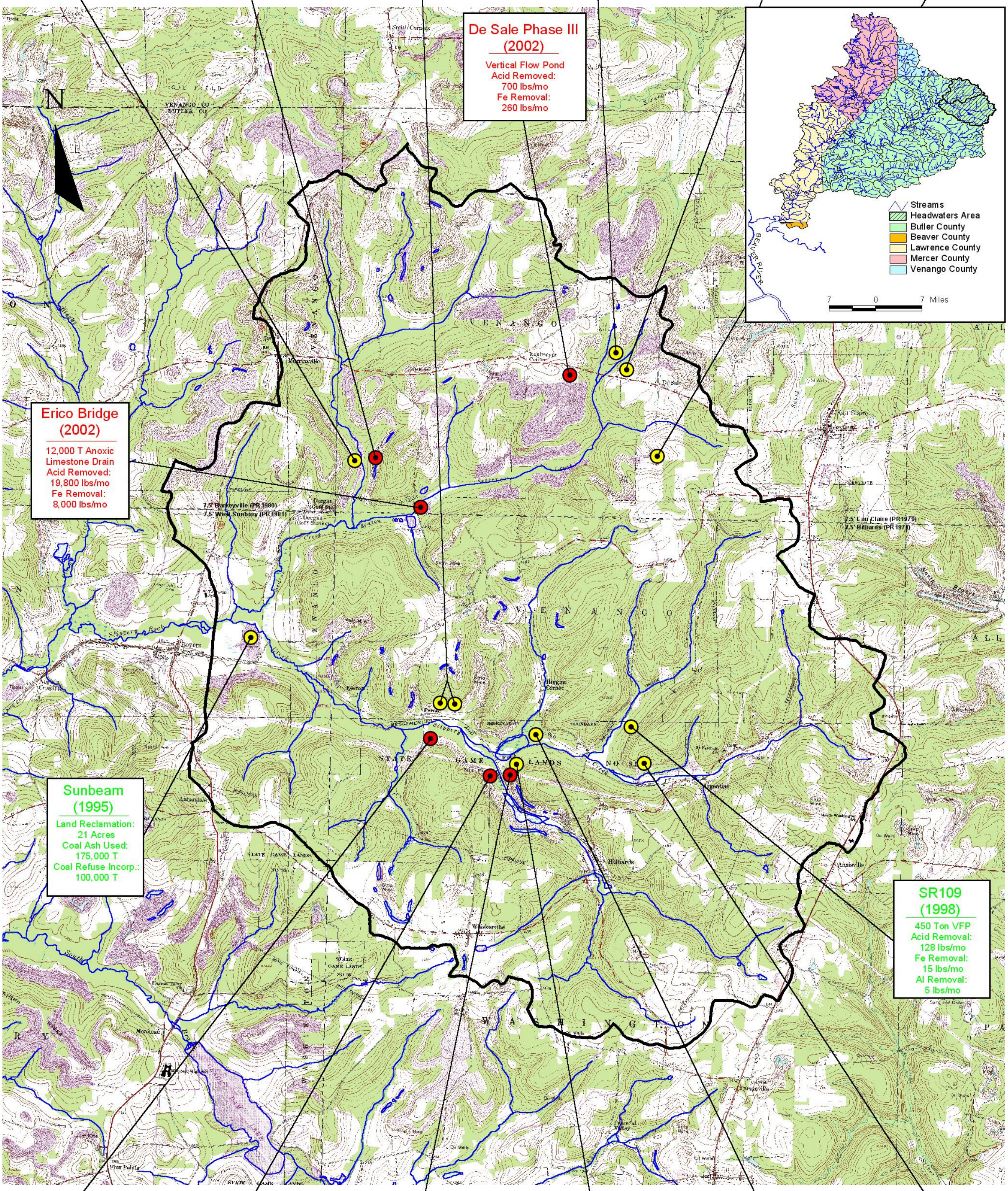
Brookville Pit (2002)
Land Reclamation: 20 Acres
Coal Ash Used: 200,000 Tons
Coal Refuse Incorporated: 94,000 T

Ferris Complex (1997)
Four Vertical Flow Systems
Acid Removed: 12,078 lbs/mo
Fe Removed: 437 lbs/mo
Al Removed: 372 lbs/mo

DeSale Phase II (2001)
4,400 Ton VFP
Acid Removed: 5,561 lbs/mo
Fe Removed: 249 lbs/mo
Al Removed: 218 lbs/mo

DeSale Phase I (2000)
3,000 Ton VFP
Acid Removed: 5,371 lbs/mo
Fe Removed: 1029 lbs/mo
Al Removed: 225 lbs/mo

Chernicky (1998)
Land Reclamation: 56 Acres
Coal Ash Utilization
Abandoned Open Pits Reclaimed



SR81(2002)
1,300 Ton ALD
Acid Removed: 173 lbs/mo
Fe Removed: 25 lbs/mo

SR96 (2002)
700 Ton ALD
Acid Removed: 292 lbs/mo
Fe Removed: 78 lbs/mo

SR89 (2002)
2,100 Ton VFP
Acid Removed: 7,127 lbs/mo
Fe Removed: 1,188 lbs/mo
Al Removed: 190 lbs/mo

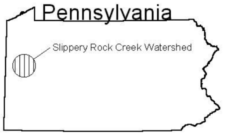
Big Bertha (1996)
900 Ton ALD
Acid Removed: 548 lbs/mo
Fe Removed: 740 lbs/mo

SR101A (1998)
900 Ton ALD
Acid Removed: 1,644 lbs/mo
Fe Removed: 800 lbs/mo

SR114 (1995)
1,450 Ton ALD
Acid Removed: 3,289 lbs/mo
Fe Removed: 2,566 lbs/mo

COMPLETED PROJECT
PROJECT UNDER CONSTRUCTION
Headwaters Study Area
Stream

2000 0 2000 4000 Feet



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.

<u>Piezometer Data Evaluation</u>

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

Upper: above clay material underlying or near 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)
30-01B	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

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 - 1233.2	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.

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]

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

Hole No.: 30-01

''RFACE ELEVATION 1245.6

'OM OF COAL ELEVATIONS: 1234.6

Groundwater Elevations and Date Measured: 1235.3 (10/25/00), 1235.8 (01/11/01), 1235.2 (10/30/00), 1236.3 (02/05/01), 1235.3 (11/06/00), 1240.9 (04/24/01), 1235.3 (11/20/00)

Surveyed by: **Earthtech, Inc.**

Survey Method: **EDM topographic survey**

Remarks: **all dimensions in 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: 17 Northing_______ Easting_______

LATITUDE _______ LONGITUDE _______

Depth	Thick-ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
5	5	5	X~--oX	spoil; nd-bn & md-gy, dry sh, cs, coal chips SWL (04/24/01)	
1	6	10		coal with binders, dry @7 1/2 coal (2) @9 1/2 cs; lb-gy, parting (1/2) SWL (10/30/00)	
13.5	2 1/2			cs; lb-to md-gy, dry @13 1/2 damp	
19	5 1/2	15		sh & cs; md-gy @15 add rod; <½ gpm @18 cs; OD (1)	
25	6	20 25 30		sh; md-to dk-gy, dry @19 sh; carb (1/2) @24 1/2 sh; carb	

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

Hole No.: 30-01A
"FACE ELEVATION 1245.6
OM OF COAL ELEVATIONS: 1234.6

Groundwater Elevations and Date Measured: 1231.1 (10/30/00) 1231.0 (02/05/01); 1230.9 (11/06/00) 1233.3 (04/24/01); 1230.7 (11/20/00); 1230.7 (01/11/01)

Surveyed by: Earthtech, Inc.
Survey Method: EDM topographic survey
Remarks: all dimensions in 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
	5		X~--oX	Spoil, dry	Piezometer
			X~--oX		
			X~--oX	SH, CS, coal chips	Screen: 20 -slot; Length 5' ; end cap 0.8'
			X~--oX		
5			X~--oX		
	6		[[[[[[[[[[[[[[[	Coal with binders, dry	Riser: 2" Sch. 40 PVC
			[[[[[[[[[[[[[[[		
				@7 1/2 coal (2)	Sand: 430 size; 25 1/2' to 19'
		10	~ ~ ~ ~ ~	@9 1/2 cs; ??-gg, parting (1/2)	Bentonite: 19' to surface
	2 1/2		~ ~ ~ ~ ~	cs; lb-to md-gy	Stick-Up: 4'
			~ ~ ~ ~ ~		
13 1/2			~ ~ ~ ~ ~	@ 13 1/2 damp	Well Diameter: 4 3/4"
	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			=======	@ 24 1/2 SH; carb	

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

Hole No.: 30-01B
-ACE ELEVATION: 1245.5
. OM OF COAL ELEVATIONS: 1234.5

Groundwater Elevations and Date Measured:
1235.7 (10/25/00) 1236.1 (01/11/01)
1235.7 (10/30/00) 1236.7 (02/05/01)
1235.6 (11/06/00) 1241.0 (04/24/01)
1235.7 (11/20/00)

Surveyed by: Earthtech, Inc.
Survey Method: EDM topographic survey
Remarks: all dimensions in 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
5	5		X~--oX	Spoil; md-bn & md-gy, dry SH, CS, coal chips	Piezometer Screen: 20 -slot; Length 5' ; end cap 0.6' Riser: 2" Sch. 40 PVC
1	6	10		coal with binders, dry @71/2 coal (2) @91/2 CS parting (1/2)	Sand: 430 size; 10 1/2' to 4 1/2' Bentonite: 4 1/2' to surface Stick-Up: 4.4
		20 30	~ ~ ~ ~ ~	cs; lb-gy, dry	Well Diameter: 4 3/4"

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

Hole No.:	30-02	Operation Name:	SR89
~FACE ELEVATION	1252.4	Method of Drilling:	Air-Rotary
OM OF COAL ELEVATIONS:	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, Inc.	Laboratory:	
Survey Method:	EDM topographic survey	UTM's Zone:	17 Northing Easting
Remarks:	all dimensions in feet	LATITUDE	LONGITUDE

Depth	Thick-ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
17 1/2	17 1/2	5, 10, 15		spoil; tan to org clayey to 5 ½, dry @5 1/2 stsh; lb-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"
20	2 1/2	20		cs; lb-gy [bottom], dry SWL (04/24/01)	
25 1/2	5 1/2	25		ss; lb-gy, fn-gn SWL (11/20/00) @23 to 24 water - 3gpm	
35 1/2	10	30, 35		stsh; md-to dk-gy muddy to dry	

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

Hole No.: 30-02A
SURFACE ELEVATION: 1252.5
BOTTOM OF COAL ELEVATIONS: 1234.0

Groundwater Elevations and Date Measured:
1234.1 (10/30/00) 1235.4 (02/05/01)
1234.0 (11/06/00) 1239.7 (04/24/01)
1234.0 (11/20/00)
1234.4 (01/11/01)

Surveyed by: Earthtech, Inc.
Survey Method: EDM topographic survey
Remarks: all dimensions in 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		X~--oX	spoil, tan to org	Piezometer
				@6 coal (1/2)	Screen: 20 -slot; Length 1.9' ;
				STSH & CS; brn & md-gy	Riser: 2" Sch. 40 PVC
		10		SWL (04/24/01)	Sand: 430 size; 19' to 16'
				@4 1/2 binders & coal (3)	Bentonite: 16' to surface
18 1/2				SWL (11/20/00)	Stick-Up: 3.7
		20		CS; lb-gy, dry	Well Diameter: 4 3/4"
		30			
		40			
		50			
		60			

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

Hole No.: 30-03
SURFACE ELEVATION 1239.1
BOTTOM OF COAL ELEVATIONS: 1228.6

Groundwater Elevations and Date Measured:
1230.1 (10/25/00) 1230.4 (01/11/01)
1230.4 (10/30/00) 1230.8 (02/05/01)
1230.3 (11/06/00) 1235.2 (04/24/01)
1230.1 (11/20/00)

Surveyed by: Earthtech, Inc.
Survey Method: EDM topographic survey
Remarks: all dimensions in 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	Thickness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
7	7		~~~~~~~	cs; bright org., v. wx, damp @1/2 cs; carb (1/2) SWL (04/24/01) some ss; bright org. fn-gn, damp	**Piezometer** Screen: 20 -slot; Length 2.1' ; Riser: 2" Sch. 40 PVC Sand: 430 size; 14' to 11'
9	2		:::::::	ss; bright org., v. wx SWL (11/20/00)	Bentonite: 15' to 14'; 11' to surface
10 1/2	1 1/2	10		coal , v. wx, clayey, damp	Stick-Up: 2.7'
14	3 1/2		:~:~:~:	ss & cs; bright org @ 11 1/2 water @ 12 ss; org., nd-gn(2), water	Well Diameter: 4 3/4"
15	1	20 … 30	~~~~~~~	cs; bright org., water	

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

Hole No.: 30-03A

SURFACE ELEVATION: 1239.6

BOTTOM OF COAL ELEVATIONS: 1229.1

Groundwater Elevations and Date Measured: 1232.4 (10/30/00), 1233.5 (02/05/01), 1232.0 (11/06/00), 1236.6 (04/24/01), 1231.8 (11/20/00), 1232.7 (01/11/01)

Surveyed by: Earthtech, Inc.

Survey Method: EDM topographic survey

Remarks: all dimensions in 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	Thickness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
	7		~~~~~~~	cs; bright org, v. wx, damp	Piezometer
			~~	@ 1/2 cs; carb (1/2)	
			~~		Screen: 20 -slot; Length 2' ;
			~~	SWL (04/24/01)	
			... ~ ~ ~ ...		Riser: 2" Sch. 40 PVC
			... ~ ~ ~ ...	some ss; bright org.	
7			~~~~~~~	fn-gn, damp	Sand: 430 size; 10 1/2' to 7'
	2		:::::::::::::::	ss; bright org., v. wx	
9			:::::::::::::::	SWL (11/20/00)	Bentonite: 7' to surface
	1 1/2	10	(coal)	coal; v. wx, clayey, damp	
					Stick-Up: 2.2'
					Well Diameter: 4 3/4"
		20			
		30			

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

Hole No.: 30-04
SURFACE ELEVATION
BOTTOM OF COAL ELEVATIONS:

Groundwater Elevations and Date Measured

Surveyed by: **Earthtech, Inc.**
Survey Method: EDM topographic survey
Remarks: **all dimensions in 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
1	1		///////////////	regolith; nd-bn	
	34		X~--oX	spoil; md-gy & ord.	
			~~	@ 1 sh & cs; md-gy, v wx (6)	
			--------	sl. 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		
			~:~:~:~		
			~:~:~:~		
			XXXXXXX		
				@25 poor return	
		30			
35				(hole collapsing)	
			-.-.-.-	STS; md-gy	

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

Hole No.: 30-05
SURFACE ELEVATION 1232.3
BOTTOM OF COAL ELEVATIONS:

Groundwater Elevations and Date Measured:
1230.1 (10/30/00) 1230.1 (02/05/01)
1229.9 (11/06/00) 1233.2 (04/25/01)
1229.8 (11/20/00)
1229.8 (01/11/01)

Surveyed by: Earthtech, Inc.
Survey Method: EDM topographic survey
Remarks: all dimensions in feet

Operation Name: SR89
Method of Drilling: Air-Rotary
Date Drilled: 10/30/00
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	Thickness	Scale	Graphic Log	Lithologic Description and Water Conditions
	1 1/2		X~--oX	spoil; md-bn, with
1 1/2			X~--oX	carb SH frogs, damp
	9		~~~~~~~~	cs; md-org, v. wx
			~~	@3 cs, gry & org mottles
			~~	
			~~	(wet, damp, and dry zones)
			~~	
			~~	SWL (04/24/01)
			[[[[[[[[[[[[[[[	@8 coal chips
		10	[[[[[[[[[[[[[[[	
			~~	SWL (11/20/00)
	3		~.~.~.~	MS & SH; md-gy & OP
			-----	@12 1/2 org stks
131/2			-----	@13 1/2 water - 3 gpm
	1 1/2		::::::::::::::::	ss; dk-gy, bn-gn
			::::::::::::::::	med hard, water
15			::::::::::::::::	
		20		
		30		

Comments

<u>Piezometer</u>

Screen: 20 -slot; Length 2 1/2' ;

Riser: 2" Sch. 40 PVC

Sand: 430 size; 15' to 11 1/2'

Bentonite: 11 1/2' to surface

Stick-Up: 1.7

Well Diameter: 4 3/4"

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

Hole No.: 30-06

⁻ᶠACE ELEVATION 1240.3

ƆM OF COAL ELEVATIONS:

Groundwater Elevations and Date Measured: 1230.8 (10/30/00) 1230.9 (02/05/01) 1230.6 (11/06/00) 1233.2 (04/24/01) 1230.6 (11/20/01) 1230.6 (01/11/01)

Surveyed by: Earthtech, Inc.

Survey Method: EDM topographic survey

Remarks: all dimensions in feet

Operation Name: SR89

Method of Drilling: Air-Rotary

Date Drilled: 10/30/00

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
2	2		X~--oX X~--oX	spoil; SH; md-gy; bony; ss frags, dry	Piezometer
3	1		~ . ~ . ~ . ~	ms & stsh; blk, dry	Screen: 20 -slot; Length 1.8' ;
6	3		-.-.-.-.-.-.	sts ; tan, org, and md- to db-gy	Riser: 2" Sch. 40 PVC
	4 1/2	10	~~~~~~~	cs; lb-to med brn, dry SWL (04/24/01) SWL (11/20/00)	Sand: 430 size; 23' to 18' Bentonite: 25' to 23'; 18' to surface Stick-Up: 4.3'
14 1/2	4		- - - - - =======	sh; md to dk-gy, blk, mild carb zones, dry	Well Diameter: 4 3/4"
17	2 1/2		======= ~ . ~ . ~ . ~	stsh; carb, dry @16 ms; carb (1')	
19	2		-.-.-.-	sts md- to dk-gy, dry	
25	6	20 30	::::::::::::::	ss; md- to dk-gy fin-gn @21 1/2 - 5 gpm	

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

Hole No.: 30-07

SURFACE ELEVATION 1229.9

BOTTOM OF COAL ELEVATIONS:

Groundwater Elevations and Date Measured: 1229.6 (10/30/00) 1229.6 (02/05/01); 1229.5 (11/06/00) 1231.7 (04/24/01); 1229.3 (11/20/00); 1229.2 (01/11/01)

Surveyed by: Earthtech, Inc.

Survey Method: EDM topographic survey

Remarks: all dimensions in feet

Operation Name: SR89

Method of Drilling: Air-Rotary

Date Drilled: 10/30/00

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	Thickness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
1 1/2	1 1/2		//////////////////	sbs; ak-bn, coal chips, damp	Piezometer
3	1 1/2		:::::::::::::::	ss; gy & bright org, clayey	Screen: 20 -slot; Length 2 1/2'
7	4		~ ~ ~ ~ ~	cs; abund. lb-gy & org mottles, damp @7 water <½ gpm	Riser: 2" Sch. 40 PVC Sand: 430 size; 15' to 10 1/2'
11 1/2	4 1/2	10	::::::::: ~ ~ ~ ~ ~	ss; org, and cs; lb-gy, wet	Bentonite: 10 1/2' to surface Stick-Up: 1.8'
15	3 1/2		:::::::::::::::	ss; md-gn, md-gy and pink sl; hard, wet @13 1/2 water - 5 gpm	Well Diameter: 4 3/4"
		20			
		30			

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

Hole No.: 30-08
SURFACE ELEVATION 1232.0
BOTTOM OF COAL ELEVATIONS:

Groundwater Elevations and Date Measured:
1230.2 (10/30/00) 1230.2 (02/05/01)
1230.1 (11/06/00) 1232.2 (04/24/01)
1229.9 (11/20/00)
1230.0 (01/11/01)

Surveyed by: Earthtech, Inc.
Survey Method: EDM topographic survey
Remarks: all dimensions in feet

Operation Name: SR89
Method of Drilling: Air-Rotary
Date Drilled: 10/30/00
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
2 1/2	2 1/2			SWL (04/24/01) sbs; org & frn; some lb-gy & black, clayey, damp SWL (11/20/00)	Piezometer Screen: 20 -slot; Length 2 1/2' Riser: 2" Sch. 40 PVC Sand: 430 size; 15' to 11 1/2' Bentonite: 11 1/2' to surface Stick-Up: 2.3' Well Diameter: 4 3/4"
6	3 1/2	5		cs; lb-gy & org mottles, damp @3 sts; org, v wx (1') @5 cs; md-gy to bn (1/2') @5 1/2 sh; md-gy to blk, cab	
15	9	10, 15		ss; lb-to md-gy, damp 9 1/2 cs; lb-gy (2) @12 1/2 wet @13 1/2 ss; mod hard water - 5 gpm @14 1/2 ss; blk	
		20, 25, 30			

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

Hole No.:	30-09	Operation Name:	SR89
SURFACE ELEVATION	1231.7	Method of Drilling:	Air-Rotary
BOTTOM OF COAL ELEVATIONS:		Date Drilled:	10/30/00
		Drilled By:	McKay&Gould Drilling Co., Darlington, PA
	1227.7 (10/30/00) 1227.5 (02/05/01)	Logged By:	McKay&Gould Drilling Co., Darlington, PA
Groundwater Elevations	1227.6 (11/06/00) 1228.2 (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 dimensions in feet	LATITUDE	LONGITUDE

Depth	Thick-ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
4 1/2	4 1/2	0–5		spoil; damp @1 sh; md-gy & fn (1) @2 cs; lb-to md-gy, brn coal chips, damp SWL (04/24/01) SWL (01/11/01)	**Piezometer** 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"
7	2 1/2	5		iron (crusty); dk-bn & dk-red twigs & leaves, wet @7 water - 1gpm	
7 1/2	1/2	10, 15, 20, 25, 30		cs; md-gy	

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

Hole No.: 30-10

SURFACE ELEVATION

BOTTOM OF COAL ELEVATIONS:

Groundwater Elevations and Date Measured

Surveyed by: Earthtech, Inc.

Survey Method: EDM topographic survey

Remarks: all dimensions in feet

Operation Name: SR89

Method of Drilling: Air-Rotary

Date Drilled: 10/30/00

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	Thickness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
2 1/2	2 1/2			cs; org & cool; wx damp	
15	12 1/2	5, 10, 15		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	
		20, 25, 30		10/30/00 - flowing well	

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

Hole No.:	30-11	Operation Name:	SR89
SURFACE ELEVATION	1229.2	Method of Drilling:	Air-Rotary
BOTTOM OF COAL ELEVATIONS:		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:	Earthtech, Inc.	Laboratory:	
Survey Method:	EDM topographic survey	UTM's Zone:	Northing Easting
Remarks:	all dimensions in feet	LATITUDE	LONGITUDE

Depth	Thick-ness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
1	1			SWL (04/24/01) ??of base; sh & ss, damp	Piezometer
2	1			SWL (01/11/01) cs, org & gy, damp	Screen: 20 -slot; Length 2 1/2' ;
4	2	5, 10, 15, 20, 25, 30		ss; org * lb-gy, nd-gn, damp	Riser: 2" Sch. 40 PVC Sand: 430 size; 4' to 1/2' Bentonite: 1/2' to surface Stick-Up: 1' Well Diameter: 4 3/4"

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

Hole No.: 30-12

-ACE ELEVATION 1220.5

OM OF COAL ELEVATIONS:

Groundwater Elevations and Date Measured: 1215.1 (10/30/00) 1217.9 (04/24/01); 1217.7 (11/06/00); 1217.7 (01/11/01); 1217.8 (02/05/01)

Surveyed by: Earthtech, Inc.

Survey Method: EDM topographic survey

Remarks: all dimensions in feet

Operation Name: SR89

Method of Drilling: Air-Rotary

Date Drilled: 10/30/00

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	Thickness	Scale	Graphic Log	Lithologic Description and Water Conditions	Comments
3	3		X~-oX	spoil; sh; dk-gy & dk-bn dry	Piezometer Screen: 20 -slot; Length 5' ; end cap 0.5' Riser: 2" Sch. 40 PVC (hole squeezing unable to place gravel pack) Stick-Up: 2' Well Diameter: 4 3/4"
8	5	05	~~~~~	cs; org some slsh; bright red v.v. muddy	
15	7	10, 15, 20, 25, 30	X~-oX	spoil, leave, twigs, bron @10 1/2 water 4-5 gpm	

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
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	9		0	249	8.3	8.1	3.4	3.3	25.0	24.1	574	20
Min				2.9	3.1	1025	8		0	249	8.3	7.9	3.4	3.3	25.0	10.8	574	11
Max				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	9		0	311	25.4	18.9	3.8	4.0	33.3	24.1	673	21
Range				0.7	0.5	252	3		0	163	34.1	32.9	1.0	1.3	16.5	26.6	240	20
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW1A	11/20/00			5.0	4.6	1345	10		1	153	76.0		3.3		41.8		676	20
MW1A	1/11/01			4.7	4.8	1145	11		3	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	54	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
Max				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		1	108	46.6	24.5	2.5	2.0	15.7	1.9	711	22
Range				1.1	1.5	200	1		3	99	60.2	18.6	1.4	0.1	39.7	1.0	88	5
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
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	9		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
Max				5.1	3.3	1546	9		0	534	54.0	41.9	3.8	3.7	47.8	46.0	1002	692
Avg				3.6	3.1	1246	9		0	367	30.3	22.6	3.4	3.1	37.4	26.5	778	349
Range				2.3	0.5	507	1		0	278	47.4	36.9	0.7	1.1	20.7	37.6	448	616
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW2	11/20/00			3.5	3.6	1043	9		0	136		12.2		2.3		12.8	527	5
MW2	1/11/01			3.6	3.6	1030	10		0	185	10.5	10.5	2.0	1.9	7.5	7.3	704	26
MW2	4/24/01			3.7	3.4	1094	11		0	163	11.5	8.8	4.4	1.9	8.1	7.6	540	43
Min				3.5	3.4	1030	9		0	136	10.5	8.8	2.0	1.9	7.5	7.3	527	5
Max				3.7	3.6	1094	11		0	185	11.5	12.2	4.4	2.3	8.1	12.8	704	43
Avg				3.6	3.5	1056	10		0	161	11.0	10.5	3.2	2.0	7.8	9.2	590	25
Range				0.2	0.2	64	2		0	49	1.0	3.4	2.4	0.4	0.6	5.5	178	38
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW2A	1/11/01			3.3	3.2	1355	9		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	9		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
Range				0.2	0.1	170	1		0	38	18.2	13.5	0.8	0.7	4.2	3.3	309	65
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW3	11/20/00			3.1	3.2	941	9		0	191		55.5		3.0		24.0	394	18
MW3	1/11/01			3.3	3.4	808	9		0	141	12.8	11.2	2.0	2.0	11.3	10.7	433	13
MW3	4/24/01			3.0	3.1	1040	9		0	254	5.1	5.0	2.8	2.8	24.9	22.1	591	4
Min				3.0	3.1	808	9		0	141	5.1	5.0	2.0	2.0	11.3	10.7	394	4
Max				3.3	3.4	1040	9		0	254	12.8	55.5	2.8	3.0	24.9	24.0	591	18
Avg				3.1	3.2	930	9		0	195	8.9	23.9	2.4	2.6	18.1	18.9	473	12
Range				0.3	0.3	232	0		0	113	7.6	50.5	0.7	1.0	13.7	13.3	197	14
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW3A	11/20/00			4.1	4.2	740	11		0	40	4.2		6.9		7.4		369	7
MW3A	1/11/01			3.6	3.7	692	8		0	83	3.1	2.8	5.2	5.0	7.3	6.4	397	15
MW3A	4/24/01			3.5	3.5	826	9		0	140	10.1	9.8	2.5	2.5	17.0	13.9	519	33
Min				3.5	3.5	692	8		0	40	3.1	2.8	2.5	2.5	7.3	6.4	369	7
Max				4.1	4.2	826	11		0	140	10.1	9.8	6.9	5.0	17.0	13.9	519	33
Avg				3.7	3.8	753	9		0	88	5.8	6.3	4.9	3.8	10.5	10.2	428	18
Range				0.6	0.7	134	3		0	101	6.9	7.0	4.3	2.5	9.7	7.5	150	26
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW5	11/20/00			5.4	6.2	755	9		26	0	2.5		2.3		2.4		374	22
MW5	1/11/01			5.7	6.2	693	6		26	0	2.0	1.5	2.1	2.1	1.5	0.0	397	23
MW5	4/24/01			5.8	6.2	723	9		20	0	1.3	0.1	2.7	2.7	1.6	0.3	417	11
Min				5.4	6.2	693	6		20	0	1.3	0.1	2.1	2.1	1.5	0.0	374	11
Max				5.8	6.2	755	9		26	0	2.5	1.5	2.7	2.7	2.4	0.3	417	23
Avg				5.6	6.2	724	8		24	0	1.9	0.8	2.4	2.4	1.8	0.1	396	19
Range				0.4	0.1	62	3		6	0	1.2	1.4	0.6	0.6	1.0	0.2	43	12
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
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	8
MW6	4/24/01			5.3	5.5	869	10		5	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
Max				5.5	6.0	1050	11		16	89	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	8
Range				0.2	0.5	198	1		10	70	16.5	3.4	0.8	0.1	0.5	0.2	143	10
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW7	11/20/00			3.6	3.7	1346	7		0	345	148.5		3.7		16.2		1213	76
MW7	1/11/01			3.9	3.7	1333	6		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	6		0	287	103.3	100.0	3.3	3.3	10.6	9.9	875	2
Max				3.9	4.0	1346	10		0	378	148.5	129.5	3.7	3.6	16.2	13.6	1213	76
Avg				3.8	3.8	1288	8		0	336	128.2	114.8	3.6	3.4	14.1	11.8	1002	32
Range				0.3	0.3	161	4		0	90	45.3	29.5	0.4	0.4	5.7	3.7	339	74
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW8	11/20/00			4.6	4.4	767	9		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
Min				4.1	4.0	767	5		0	106	40.3	39.0	6.3	6.2	3.7	2.9	482	16
Max				4.6	4.4	880	10		0	129	209.0	212.3	7.1	7.1	4.6	3.8	582	24
Avg				4.3	4.2	821	8		0	118	96.9	125.6	6.7	6.6	4.3	3.4	528	20
Range				0.5	0.4	113	5		0	23	168.8	173.3	0.8	0.9	0.9	0.8	99	8
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW9	11/20/00			4.3	4.0	848	9		0	158	57.5	34.4	4.3	3.2	32.4	8.2	565	144
MW9	1/11/01			4.3	3.7	837	8		0	199	52.8	44.8	3.1	3.0	10.0	8.3	536	67
MW9	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	9		0	178	53.9	29.5	3.8	3.3	20.1	9.2	557	83
Range				0.3	0.3	36	2		0	41	6.0	35.6	1.2	0.6	22.4	3.0	35	107
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
MW11	11/20/00			3.9	3.9	773	7		0	101		80.0		2.9		4.5	446	129
MW11	1/11/01			4.1	3.8	827	6		0	119	12.9	10.0	4.9	4.6	14.1	11.8	495	6
MW11	4/24/01			3.8	3.6	834	12		0	159	18.0	13.6	4.9	4.4	17.9	13.3	546	10
Min				3.8	3.6	773	6		0	101	12.9	10.0	4.9	2.9	14.1	4.5	446	6
Max				4.1	3.9	834	12		0	159	18.0	80.0	4.9	4.6	17.9	13.3	546	129
Avg				3.9	3.8	811	8		0	126	15.4	34.5	4.9	4.0	16.0	9.8	496	48
Range				0.3	0.3	61	6		0	58	5.2	70.1	0.0	1.7	3.8	8.8	100	123
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
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
Min				3.8	3.4	1506	8		0	369	212.8	194.3	6.4	6.4	0.8	0.3	949	32
Max				4.2	3.6	1670	10		0	489	220.0	196.8	7.0	6.6	0.8	0.6	970	36
Avg				4.0	3.5	1588	9		0	429	216.4	195.5	6.7	6.5	0.8	0.4	959	34
Range				0.4	0.2	164	2		0	120	7.3	2.5	0.5	0.2	0.0	0.3	21	4
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
SR89	7/27/95		30		2.9				0	314	48.4		5.1		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	3
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		9.8		962	26
SR89	2/22/96				3.0				0	206	30.4		5.2		6.9		449	3
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	3
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	14
SR89	7/24/96	Estimated	50		3.2				0	254	70.0		5.5		7.8		711	6
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		97	0
SR89	4/15/97	Measured	66		3.4				0	188	53.5		4.9		8.3		527	8
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	29		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	8
SR89	5/19/98	Measured	145		3.1				0	184	33.2		4.3		6.9		482	4
SR89	9/16/98	Estimated	30		3.1				0	266	52.4		4.4		7.0		790	0

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
SR89	3/31/99				3.0				0	236	39.0		5.4		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	6
Min			29		2.7	1663	28		0	2	0.8	15.6	0.8	3.8	0.0	7.5	97	0
Max			145		6.0	1663	28		13	391	94.1	15.6	6.2	3.8	11.9	7.5	962	26
Avg			52		3.1	1663	28		0	249	52.3	15.6	5.0	3.8	8.1	7.5	559	6
Range			116		3.3	0	0		13	389	93.3	0.0	5.4	0.0	11.9	0.0	865	26
Total Loading (lb/day)									0	156	32.8	9.8	3.1	2.4	5.1	4.7		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
56.1	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
Min				6.9	6.7	192	21		17	0	0.4	0.1	0.4	0.4	0.1	0.1	51	5
Max				6.9	6.7	192	21		17	0	0.4	0.1	0.4	0.4	0.1	0.1	51	5
Avg				6.9	6.7	192	21		17	0	0.4	0.1	0.4	0.4	0.1	0.1	51	5
Range				0.0	0.0	0	0		0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
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	2
Min				6.5	6.4	344	22		8	0	0.8	0.1	1.0	1.0	0.1	0.1	146	2
Max				6.5	6.4	344	22		8	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	2
Range				0.0	0.0	0	0		0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
63	6/7/01			6.0	6.0	349	22		6	1	2.4	1.3	1.0	1.0	0.1	0.1	161	6
Min				6.0	6.0	349	22		6	1	2.4	1.3	1.0	1.0	0.1	0.1	161	6
Max				6.0	6.0	349	22		6	1	2.4	1.3	1.0	1.0	0.1	0.1	161	6
Avg				6.0	6.0	349	22		6	1	2.4	1.3	1.0	1.0	0.1	0.1	161	6
Range				0.0	0.0	0	0		0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
N. END OF WL (STA NDING)	4/9/01			2.6	2.8	1589	25		0	313	39.9		5.3		12.0		777	6
Min				2.6	2.8	1589	25		0	313	39.9		5.3		12.0		777	6
Max				2.6	2.8	1589	25		0	313	39.9		5.3		12.0		777	6
Avg				2.6	2.8	1589	25		0	313	39.9		5.3		12.0		777	6
Range				0.0	0.0	0	0		0	0	0.0		0.0		0.0		0	0
Total Loading (lb/day)																		

SR89 Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
N.E. END OF WL, P IT	4/9/01			3.3	3.7	884	23		0	219	89.1		4.1		6.7		541	74
Min				3.3	3.7	884	23		0	219	89.1		4.1		6.7		541	74
Max				3.3	3.7	884	23		0	219	89.1		4.1		6.7		541	74
Avg				3.3	3.7	884	23		0	219	89.1		4.1		6.7		541	74
Range				0.0	0.0	0	0		0	0	0.0		0.0		0.0		0	0
Total Loading (lb/day)																		

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, Al, 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 gpm	pH	Acidity mg/L	Iron mg/L	Manganese mg/L	Aluminum mg/L
66	2.8	368	94	6	12

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

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

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

Pollutant	Loading		
	lbs./day	lbs./month	tons/year
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.

<u>Vertical Flow Pond(VFP)</u>

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 layer 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.

<u>Aerobic Wetland(WL)</u>

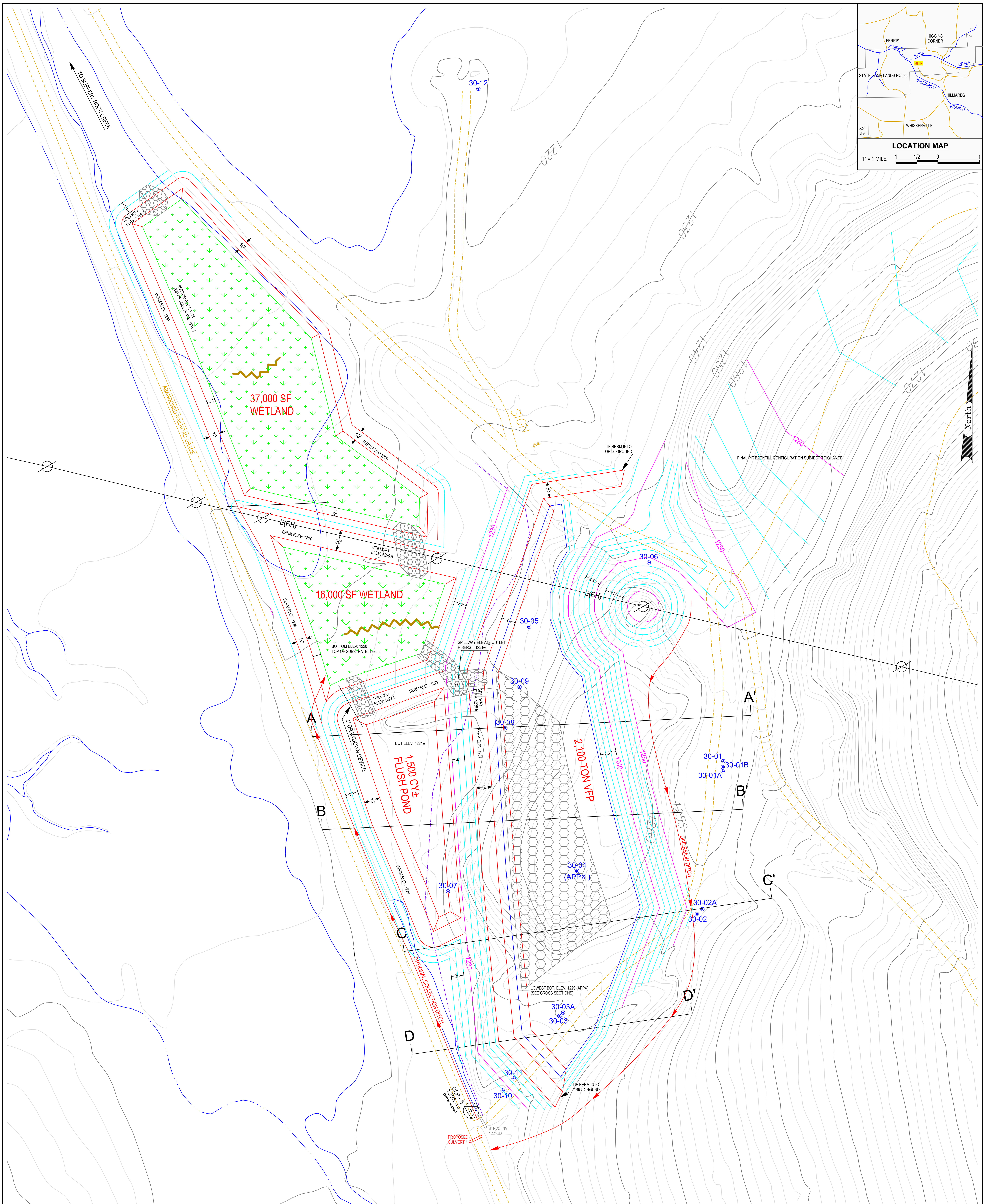
An aerobic wetland will be constructed to facilitate the oxidation, hydrolysis, and precipitation of metals. The sizing criteria for iron removal from alkaline mine drainage in an aerobic wetland is between 10-20 g per square meter per day(Hedin et al, 1994). Using the more conservative 10 g per square 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.

<u>Diverted Drainage</u>

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

- EXISTING CONTOUR - INDEX
- EXISTING CONTOUR - INTERMEDIATE
- PROPOSED CONTOUR - INDEX
- PROPOSED CONTOUR - INTERMEDIATE
- PASSIVE TREATMENT SYSTEM COMPONENT
- EX. CULVERT/WATER STRUCTURE
- DIRECTIONAL BAFFLE (APPX. LOCATION)
- WATER
- DIRT/UNIMPROVED ROAD
- TRAILS
- CLAYSTONE CROPLINE
- UTILITY POLE
- RIP RAP SPILLWAY (R-4)
- PROPOSED CONSTRUCTED WETLAND AREA
- HIGH CCE (~90%) AASHTO #1 LIMESTONE
- 2.5:1 DESIGN SLOPE SPECIFICATION
- BERM WIDTH DIMENSION
- E(OH) UTILITY LINES (OVERHEAD)
- A A' CROSS-SECTION
- 30-01 MONITORING WELL

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.
Call for all utilities: PA One Call 1-800-242-1776 Serial #1071633
Contour Interval: 2'
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.

Stream Restoration Through Coal Mine Drainage Abatement

Slippery Rock Creek Headwaters Project

SHEET 1 OF 3 (PLAN VIEW)

PASSIVE TREATMENT SYSTEM DESIGN PLAN

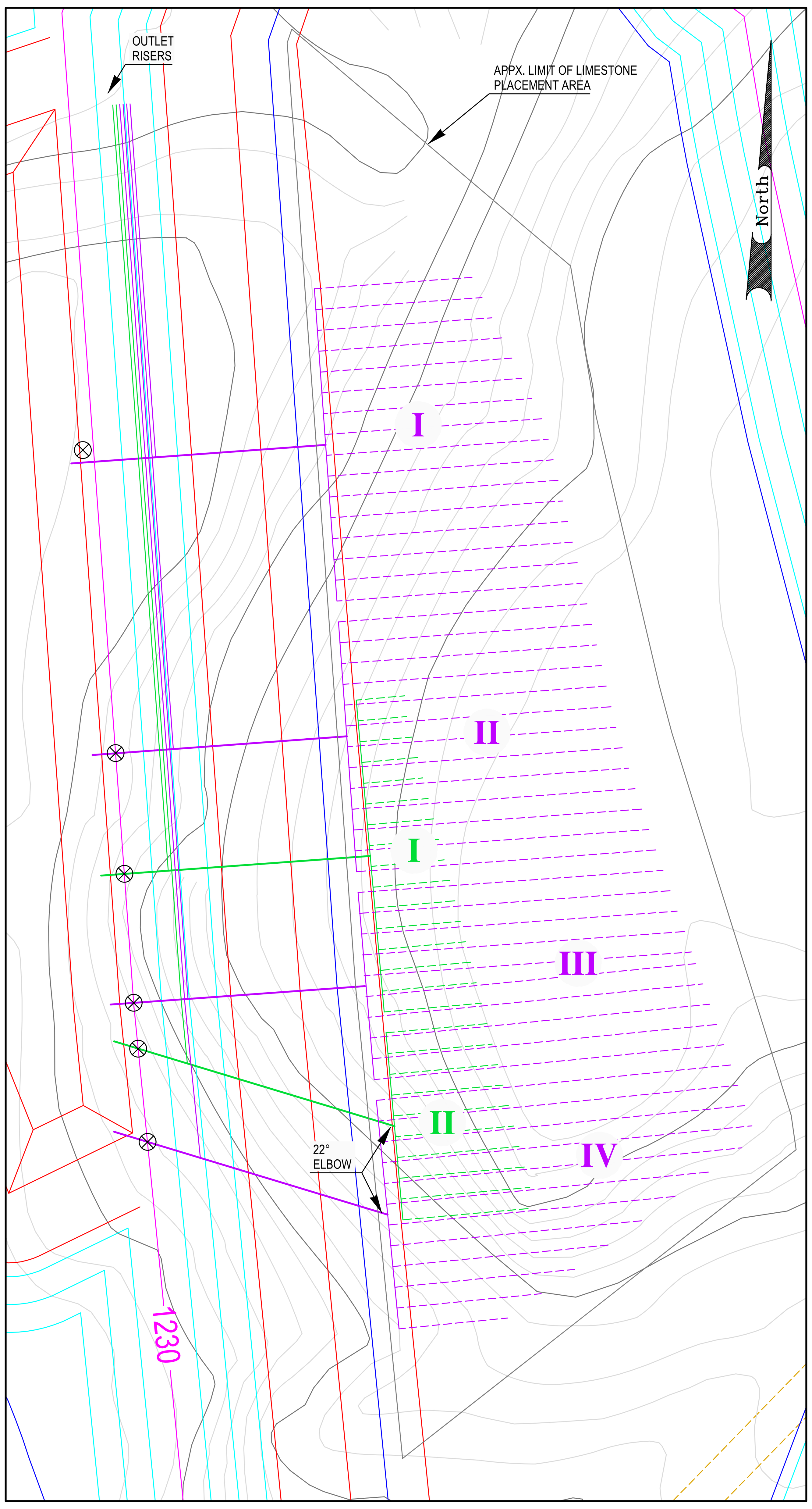
SR89 DISCHARGE

Slippery Rock Watershed Coalition
in cooperation with
Stream Restoration Incorporated
Washington Twp., Butler Co., PA

Scale: 1" = 40' Date: 12/2001

BioMost, Inc., Cranberry Twp., PA

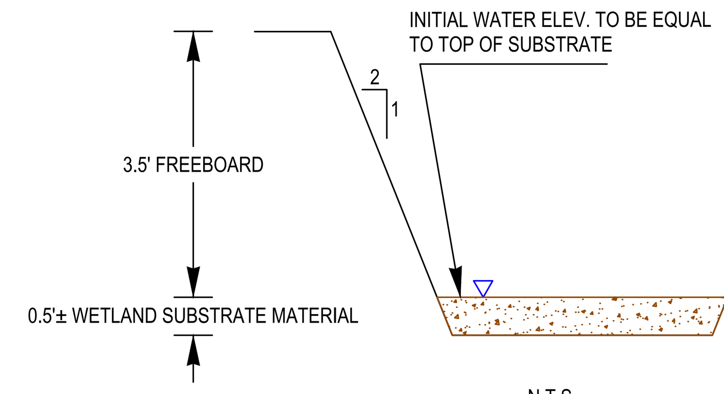
103001/pts1



I LOWER TIER SECTOR   I UPPER TIER SECTOR   ⊗ VALVE

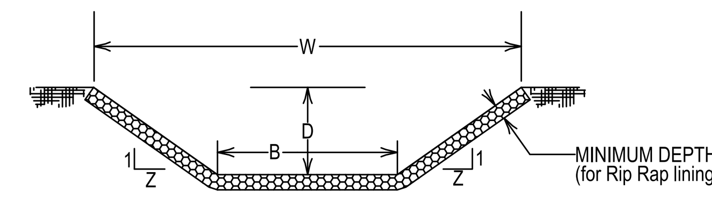
SCALE: 1" = 20'

UNDER DRAIN LAYOUT DETAIL



N.T.S.

WETLAND TYPICAL



N.T.S.

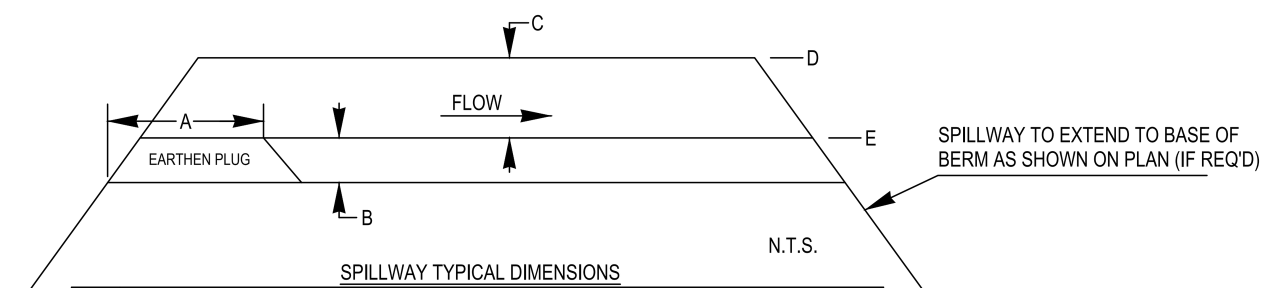
RIP-RAPPED CHANNELS

CHANNEL TYPE	W	B**	D	Z	LINING
SPILLWAY	14.0*	10	1.0*	2	R-4
-	-	-	-	-	-

*TO BE ADJUSTED AS NEEDED TO MEET ELEVATIONS AS NOTED ON THE PLAN
**MAY BE ADJUSTED DUE TO FIELD OR OTHER CONDITIONS

N.T.S.

RIP RAP CHANNEL DETAIL



N.T.S.

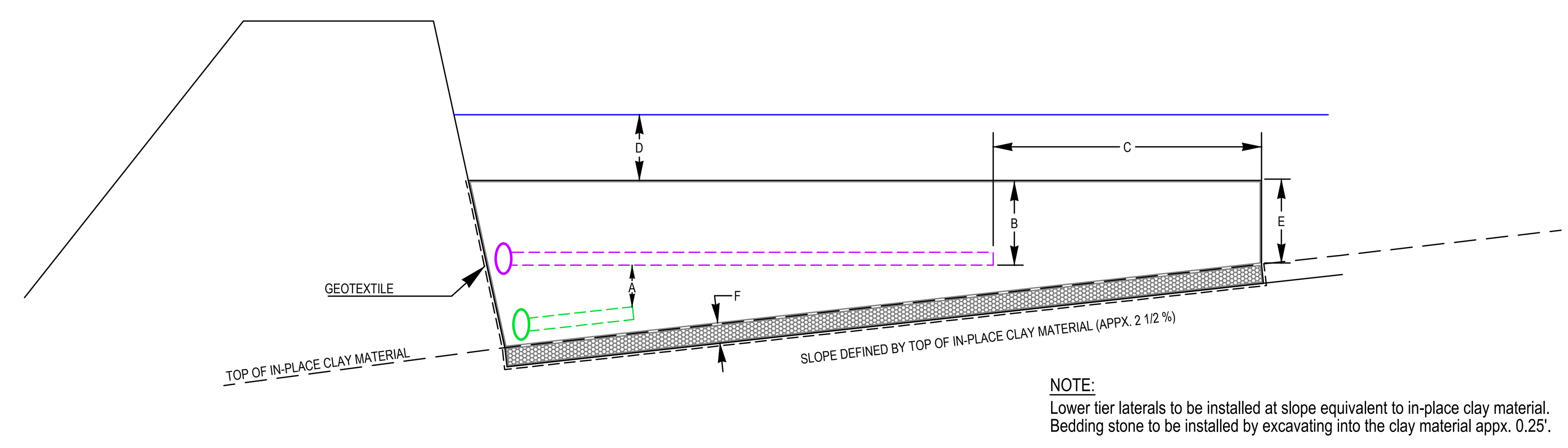
SPILLWAY TYPICAL DIMENSIONS

A	EARTHEN PLUG LENGTH (4' ±)
B	OVER EXCAVATION (EQUAL TO RIP-RAP MINIMUM DEPTH AS PER DATA CHART)
C	DEPTH OF SPILLWAY (TOP OF BERM ELEVATION TO SPILLWAY ELEVATION)
D	TOP OF BERM ELEVATION AS PER PLAN
E	SPILLWAY ELEVATION AS PER PLAN (TOP OF RIP RAP)

SPILLWAY SECTION TYPICAL

RIP-RAP DATA CHART

NCSA No.	AVG. STONE SIZE (d50)	MIN. DEPTH A
R-2	1 1/2"	3"
R-3	3"	6"
R-4	6"	12"
R-5	9"	18"
R-6	12"	24"
R-7	18"	36"
R-8	24"	48"

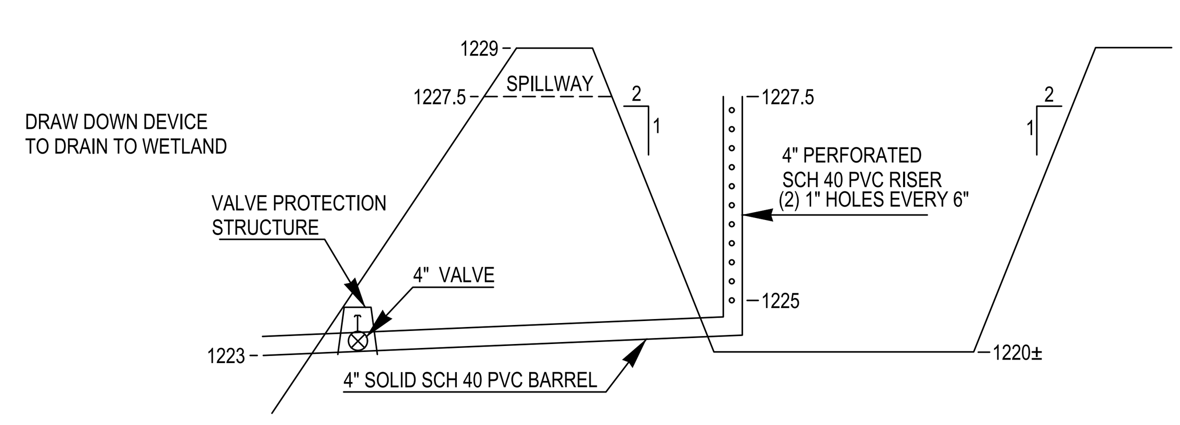


NOTE:
Lower tier laterals to be installed at slope equivalent to in-place clay material.
Bedding stone to be installed by excavating into the clay material appx. 0.25'.

N.T.S.

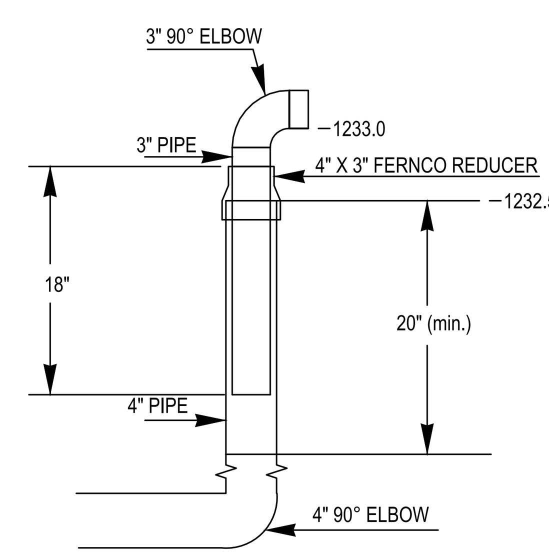
A	1' MIN. (FROM INVERT OF UPPER TIER TO TOP OF LOWER TIER)
B	1.5' (FROM TOP OF LIMESTONE TO INVERT OF UPPER TIER)
C	10' MIN. (FROM UPSLOPE EDGE OF LIMESTONE TO END OF UPPER TIER LATERAL)
D	1.0' (DESIGN WATER DEPTH)
E	1.0' (MINIMUM LIMESTONE THICKNESS)
F	0.25' (BEDDING STONE THICKNESS - 0.25' AASHTO #57)

VERTICAL FLOW POND SECTION



N.T.S.

4" DRAW DOWN DEVICE DETAIL



SCALE: 1" = 1'

OUTLET RISER DETAIL

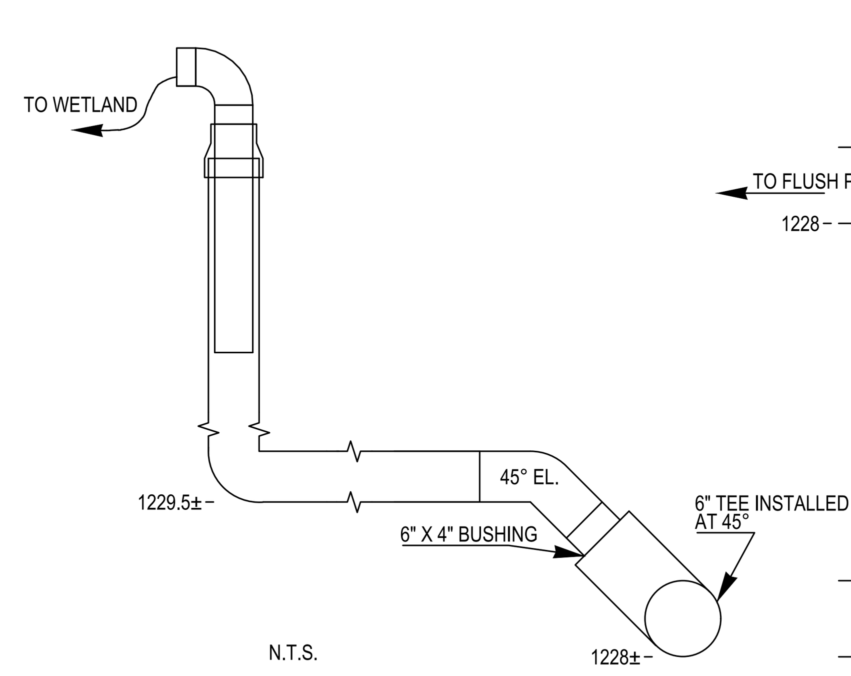
UNDER DRAIN PIPE DATA TABLE

4" Perf Upper Tier
(Starting from North)

Lateral #	Sector	Length (ft)
1	1	34.1
2	1	48.7
3	1	48.0
4	1	46.9
5	1	45.0
6	1	43.2
7	1	41.4
8	1	39.6
9	1	37.8
10	1	35.9
11	1	49.4
12	1	50.2
13	1	50.9
14	1	51.6
15	1	52.3
16	1	53.0
17	2	53.7
18	2	54.4
19	2	55.2
20	2	55.9
21	2	56.6
22	2	57.3
23	2	58.0
24	2	59.1
25	2	60.1
26	2	61.2
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	76.8
41	4	77.9
42	4	79.0
43	4	80.1
44	4	77.5
45	4	69.8
46	4	62.1
47	4	54.4
48	4	46.7
49	4	39.0
50	4	31.3
51	4	23.6

4" Perf Lower Tier
(Starting from North)

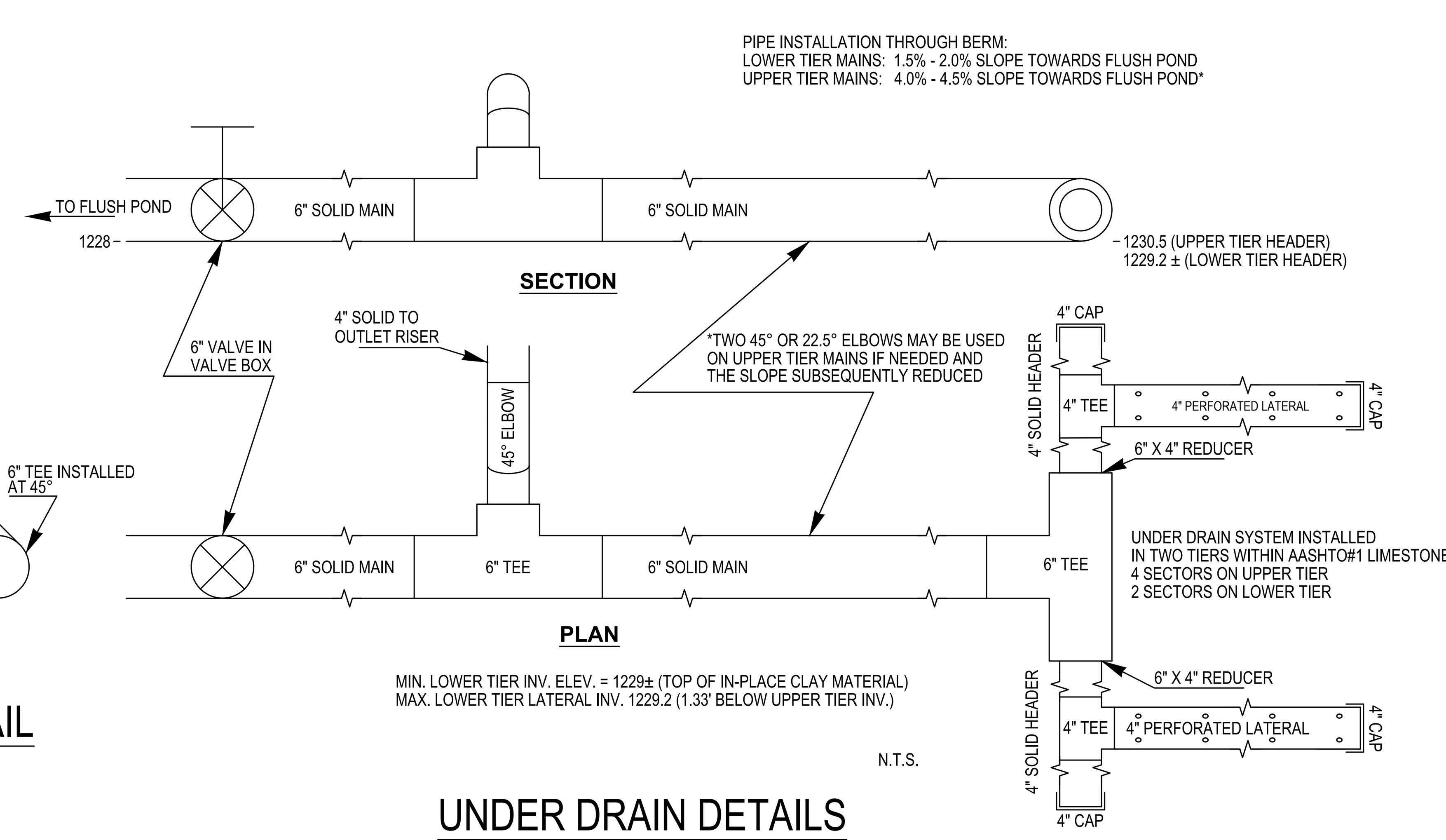
Lateral #	Sector	Length (ft)
1	1	10.5
2	1	10.5
3	1	11.3
4	1	12.0
5	1	12.8
6	1	13.5
7	1	14.3
8	1	15.0
9	1	15.8
10	1	16.6
11	1	17.3
12	1	18.1
13	1	18.8
14	1	19.6
15	1	20.3
16	1	21.1
17	2	21.8
18	2	22.6
19	2	23.3
20	2	24.1
21	2	24.8
22	2	25.6
23	2	26.4
24	2	27.1
25	2	27.9
26	2	27.1



N.T.S.

DISCHARGE PIPE DETAIL

PIPE INSTALLATION THROUGH BERM:
LOWER TIER MAINS: 1.5% - 2.0% SLOPE TOWARDS FLUSH POND
UPPER TIER MAINS: 4.0% - 4.5% SLOPE TOWARDS FLUSH POND*



MIN. LOWER TIER INV. ELEV. = 1229± (TOP OF IN-PLACE CLAY MATERIAL)
MAX. LOWER TIER LATERAL INV. 1229.2 (1.33' BELOW UPPER TIER INV.)

N.T.S.

UNDER DRAIN DETAILS

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.
Call for all utilities: PA One Call 1-800-242-1776 Serial #1071633
Contour Interval: 2'

LEGEND

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

LENGTH AS PER TABLE — VFP UPPER TIER LATERALS - 4" PERFORATED*
LENGTH AS PER TABLE — VFP LOWER TIER LATERALS - 4" PERFORATED*
UPPER TIER HEADERS - 4" SOLID
UPPER TIER MAINS - 6" SOLID
LOWER TIER HEADERS - 4" SOLID
LOWER 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

Stream Restoration Through Coal Mine Drainage Abatement

Slippery Rock Creek Headwaters Project

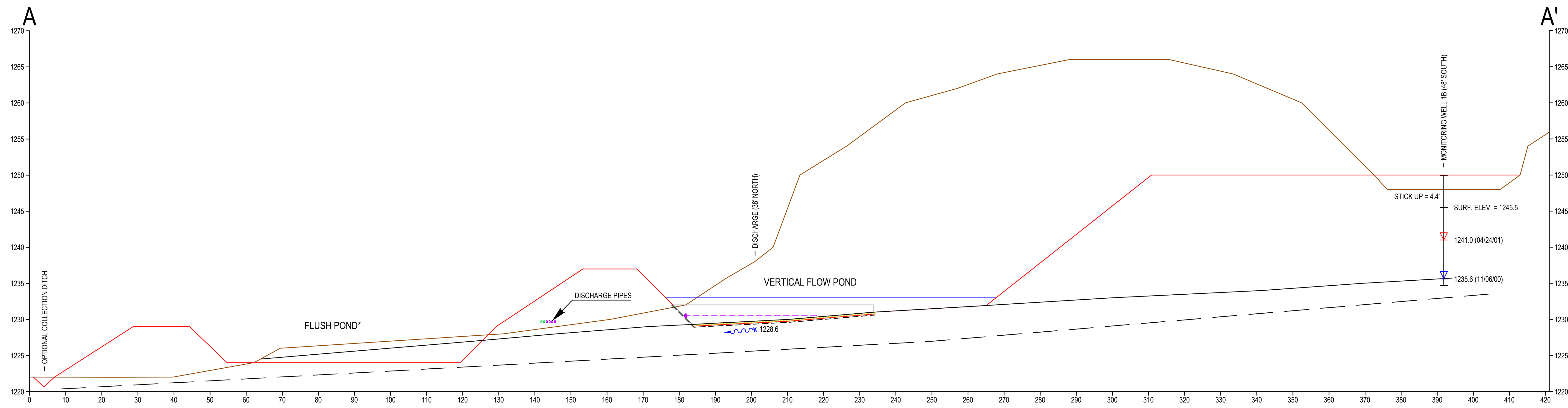
SHEET 2 OF 3 (DETAILS)

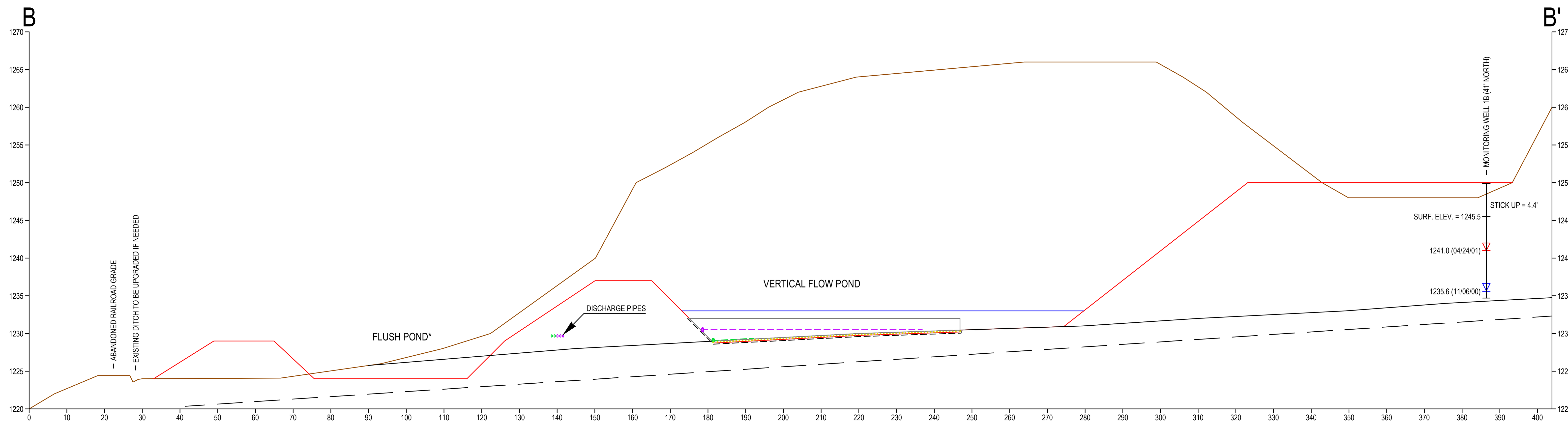
PASSIVE TREATMENT SYSTEM DESIGN PLAN

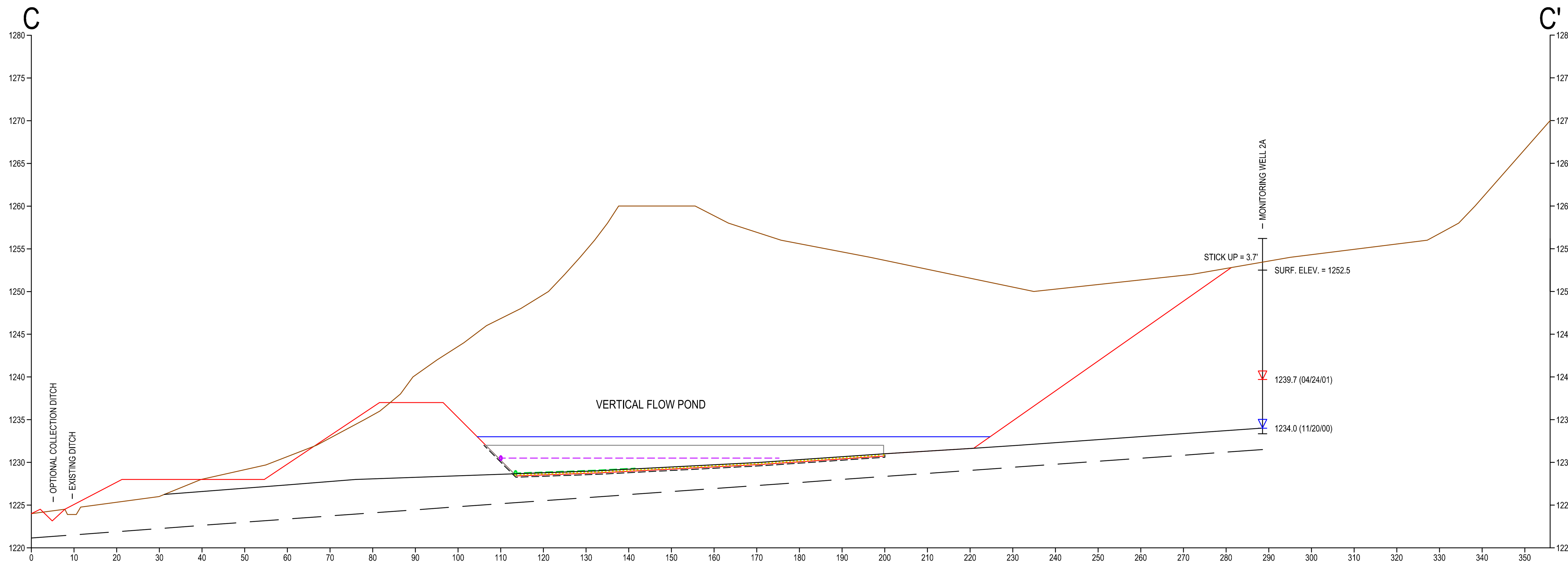
SR89 DISCHARGE

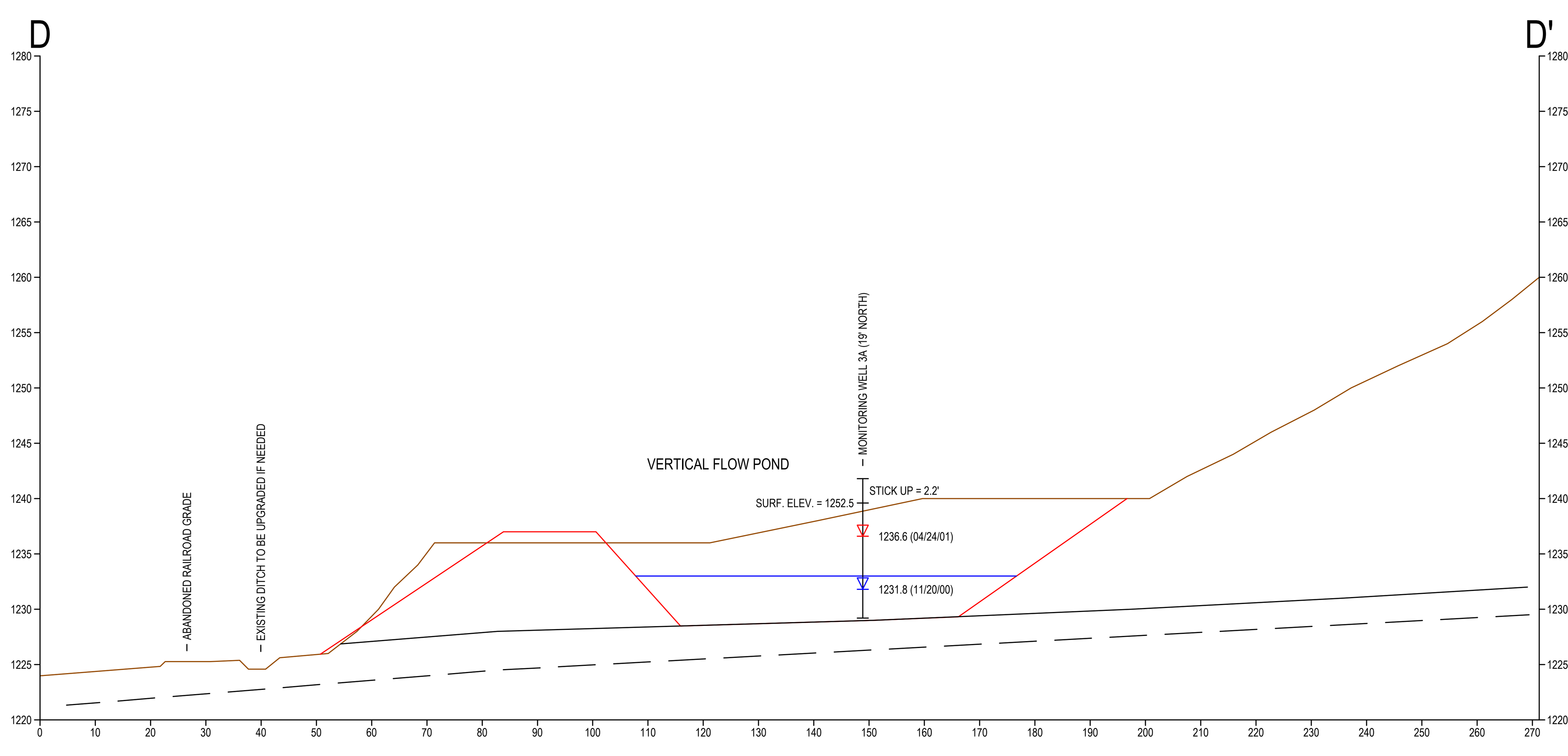
Slippery Rock Watershed Coalition
in cooperation with
Stream Restoration Incorporated
Washington Twp., Butler Co., PA
Scale: 1" = As Shown Date: 12/2001
BioMost, Inc., Cranberry Twp., PA

103001sts2









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

NOTES:

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.

LEGEND

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

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

103001/sbs3

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

D.M. DeNicola and M.G. Stapleton

Slippery Rock University

Slippery Rock, PA 16057

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

Abstract

A 70 km^2 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.

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

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 ($CaSO_4$) 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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Table 1. Sample dates and codes for biological and chemical parameters.

Date	Code	pH, Alk & Dis. Metals	Total Aq. Metals	Algae	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 2 Cont.

Site	Date	Temp C	pH	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

Table 3 Cont.

Station #	Quarter	Aluminum Soluble (mg/l)	Iron Soluble (mg/l)	Manganese Soluble (mg/l)	Calcium Soluble (mg/l)	Magnesium Soluble (mg/l)	Silicon Soluble (mg/l)	Cadmium Soluble (mg/l)	Lead Soluble (mg/l)	Nickel Soluble (mg/l)	Zinc Soluble (mg/l)	Aluminum Total (mg/l)	Iron Total (mg/l)	Manganese Total (mg/l)	Calcium Total (mg/l)	Magnesium Total (mg/l)	Silicon Total (mg/l)	Cadmium Total (mg/l)	Lead Total (mg/l)	Nickel Total (mg/l)	Zinc Total (mg/l)
44	Spring 01	0.28	1.41	2.38	27.30	10.78	4.51	0.02	0.21	0.04	0.06	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
46	Spring 01	0.26	1.52	1.30	37.70	11.48	4.73	0.03	0.28	0.03	0.04	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
49	Spring 01	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
60	Spring 01	0.31	1.91	0.68	29.42	9.79	3.89	0.02	0.21	0.02	0.02	2.45	2.20	0.59	26.42	8.52	4.27	0.02	0.22	0.03	0.01
61	Spring 01	0.28	0.08	0.21	7.87	3.77	3.01	0.01	0.11	0.01	0.02	1.58	0.28	0.19	7.61	3.40	3.53	0.01	0.12	0.01	0.00
62	Spring 01	0.29	0.44	1.01	21.87	9.33	3.88	0.02	0.18	0.03	0.10	8.30	1.00	0.90	21.91	8.28	4.84	0.02	0.19	0.03	0.02
63	Spring 01	0.31	1.235	0.67	28.045	9.37	3.865	0.02	0.235	0.025	0.025	2.035	1.41	0.58	24.885	8.51	3.78	0.025	0.195	0.015	0.035
64	Spring 01	0.30	0.37	0.93	32.82	9.75	4.24	0.03	0.27	0.03	0.02	2.13	0.56	0.83	29.24	9.17	4.17	0.03	0.22	0.02	0.02
65	Spring 01	0.27	1.16	3.14	63.11	19.35	4.00	0.05	0.37	0.04	0.04	3.46	1.60	2.79	57.58	18.08	4.18	0.05	0.35	0.03	0.04
67	Spring 01	0.27	0.18	0.85	31.77	9.98	3.85	0.03	0.23	0.02	0.01	2.37	0.44	0.76	28.35	9.28	3.82	0.03	0.21	0.02	0.02
68	Spring 01	0.26	2.57	7.30	119.91	38.93	4.65	0.07	0.57	0.07	0.08	2.44	3.07	6.61	107.91	35.73	4.58	0.07	0.56	0.06	0.08
WC	Spring 01	0.26	0.10	0.09	44.31	9.01	1.52	0.03	0.28	0.02	0.01	1.48	0.29	0.07	40.31	8.53	1.58	0.04	0.29	0.01	0.00
44	Fall 01	0.28	5.43	3.26	71.47	20.29	9.08	0.05	0.34	0.04	0.07	0.70	1.68	0.98	19.84	5.55	3.14	0.02	0.16	0.01	0.01
46	Fall 01	0.26	2.42	6.685	121.1	34.88	9.29	0.07	0.5	0.05	0.09	1.39	1.225	1.745	29.24	8.355	2.97	0.025	0.21	0.025	0.01
49	Fall 01	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
60	Fall 01	0.25	0.39	0.39	73.38	18.05	3.87	0.05	0.34	0.01	0.06	6.00	1.22	0.22	30.68	7.32	2.73	0.03	0.22	0.01	0.00
61	Fall 01	0.24	0.28	0.29	17.10	7.05	4.35	0.02	0.11	0.01	0.01	1.08	0.44	0.10	5.88	2.24	2.26	0.02	0.13	0.02	-0.01
62	Fall 01	0.26	2.63	3.31	78.08	25.30	7.21	0.05	0.34	0.04	0.08	1.67	1.35	0.83	19.64	5.91	2.43	0.02	0.21	0.02	0.00
63	Fall 01	0.255	1.515	0.645	103.115	25.53	4.985	0.06	0.435	0.015	0.09	1.55	1.645	0.22	31.595	7.805	2.21	0.035	0.305	0.03	0.005
64	Fall 01	0.30	1.43	3.69	74.50	20.07	5.07	0.05	0.32	0.03	0.09	1.96	1.06	1.53	29.76	8.01	2.73	0.03	0.32	0.05	0.02
65	Fall 01	0.25	0.25	3.99	130.78	38.40	4.17	0.07	0.50	0.03	0.03	3.00	0.53	1.67	55.52	16.26	2.42	0.05	0.39	0.05	0.02
67	Fall 01	0.24	0.48	1.83	108.50	30.10	5.75	0.06	0.44	0.02	0.04	3.53	0.69	0.57	34.34	9.20	2.88	0.04	0.29	0.04	0.01
68	Fall 01	0.27	1.32	13.14	270.99	92.87	6.13	0.12	0.94	0.07	0.09	3.61	0.60	3.11	66.32	22.48	2.14	0.05	0.47	0.04	0.02
WC	Fall 01	0.24	0.04	0.09	67.06	13.92	2.23	0.04	0.27	0.01	0.02	1.38	0.11	0.05	24.28	5.12	1.23	0.03	0.26	0.04	0.00

Tab. 5

Run: Relative abundance of taxa in epipelon 1999-20001, pooled by date. Relative abundnace
Taxa in bold are indicative of acidic conditions.

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. venter	0.0000	0.0006	0.0121	0.0000	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	0.0000	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

Table 7

Change in percent of epipelic diatoms that are acid indicators.

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

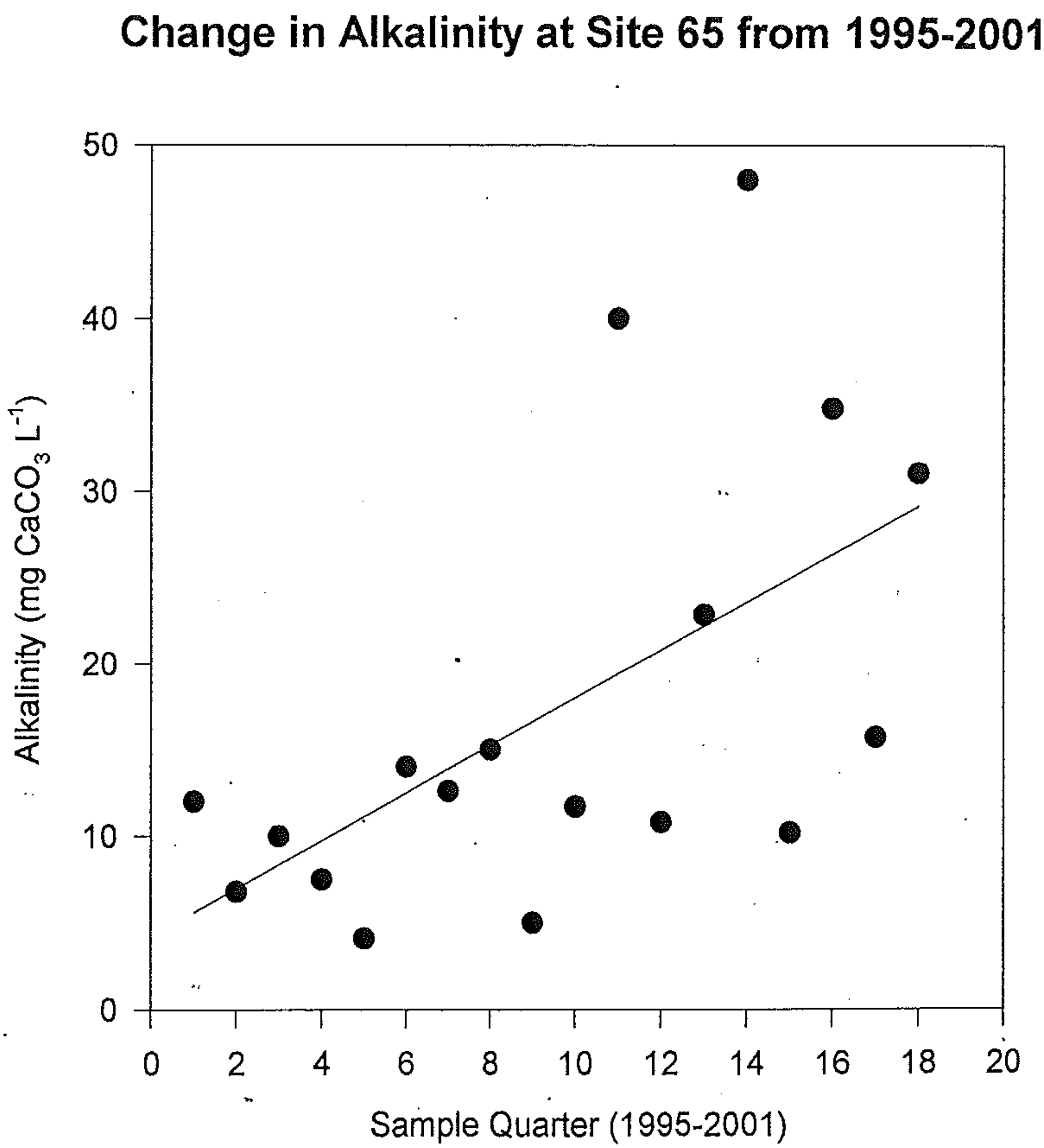
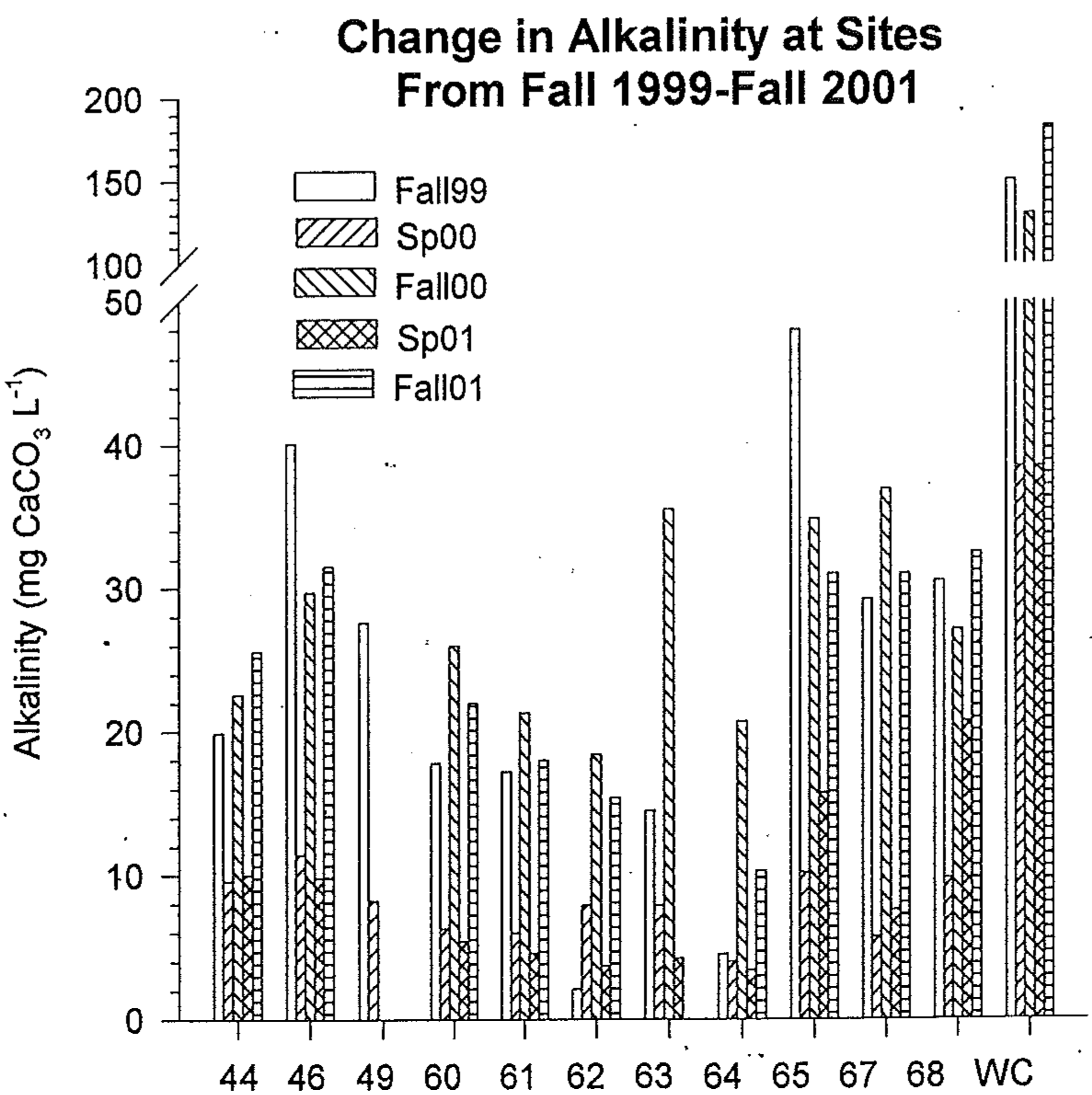

Change in Alkalinity at Site 65 from 1995-2001
Alkalinity (mg CaCO3 L-1)
Sample Quarter (1995-2001)
0
10
20
30
40
50
0
2
4
6
8
10
12
14
16
18
20

Figure 7



Change in Alkalinity at Sites
From Fall 1999-Fall 2001
Fall99
Sp00
Fall00
Sp01
Fall01
Alkalinity (mg $CaCO_3$ L^{-1})
200
150
100
50
40
30
20
10
0
44
46
49
60
61
62
63
64
65
67
68
WC

Figure 3

Change in Alkalinity at Site 68 from 1995-2001

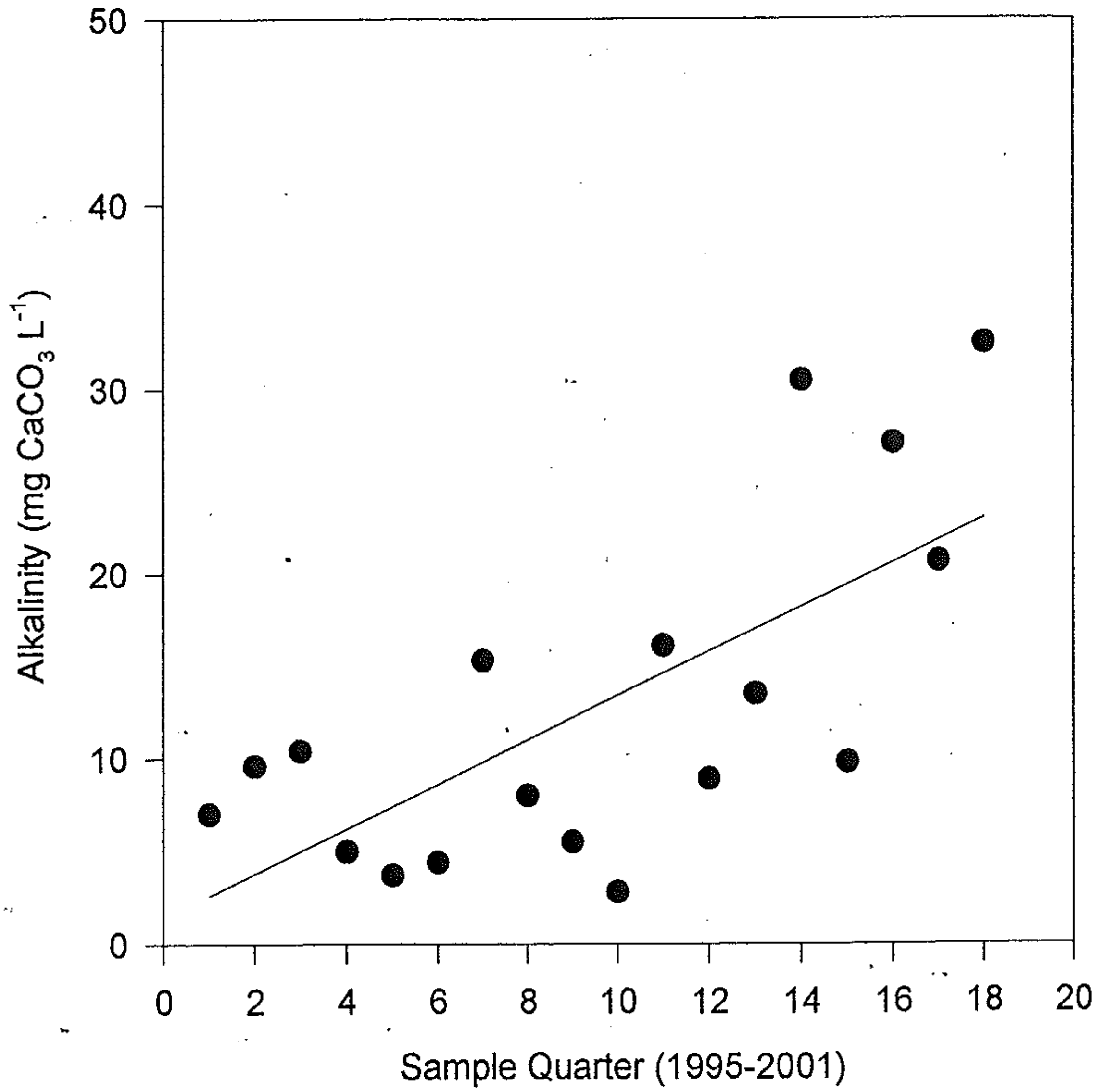
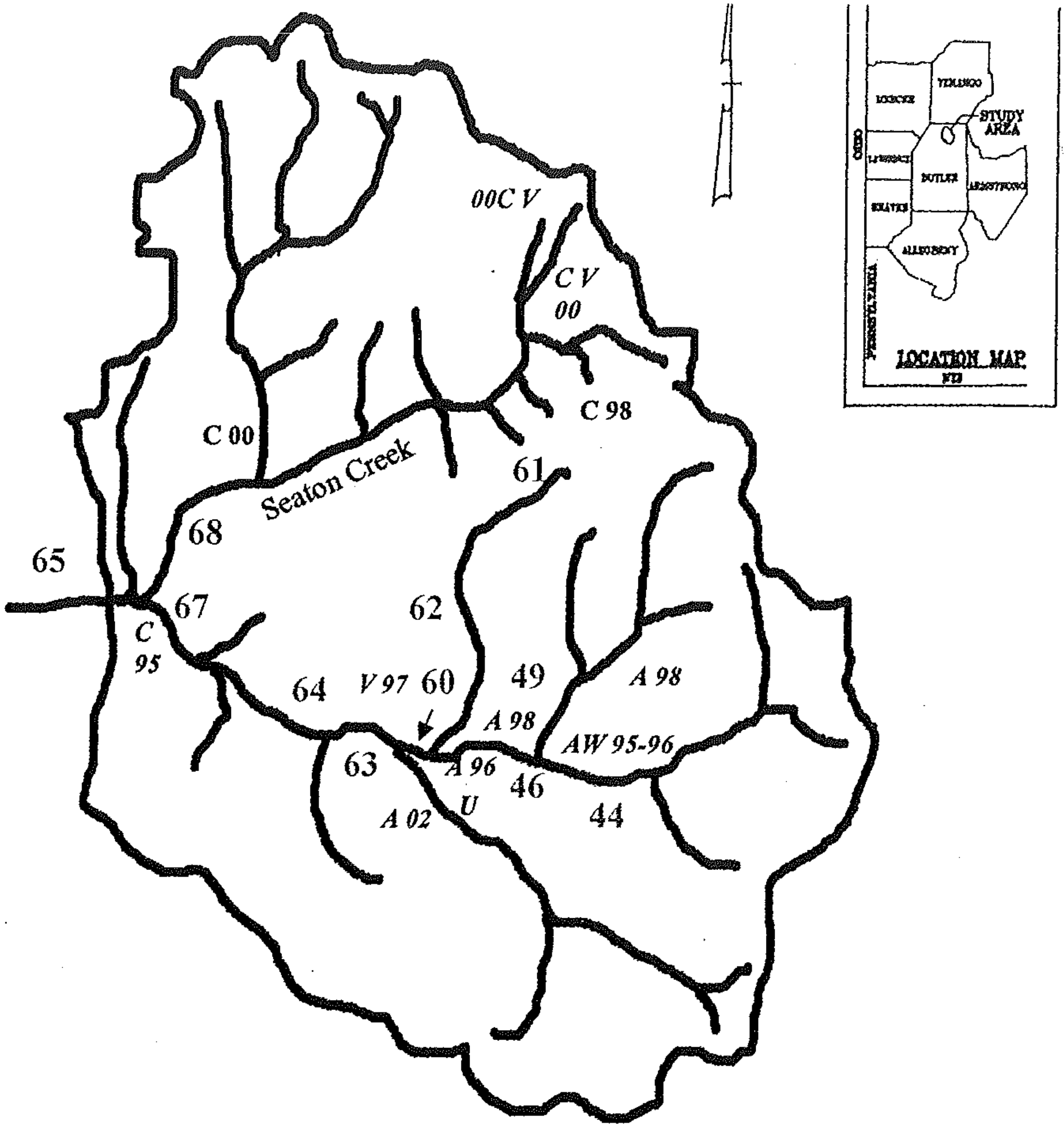


Figure 5



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

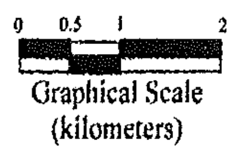


Figure 1

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

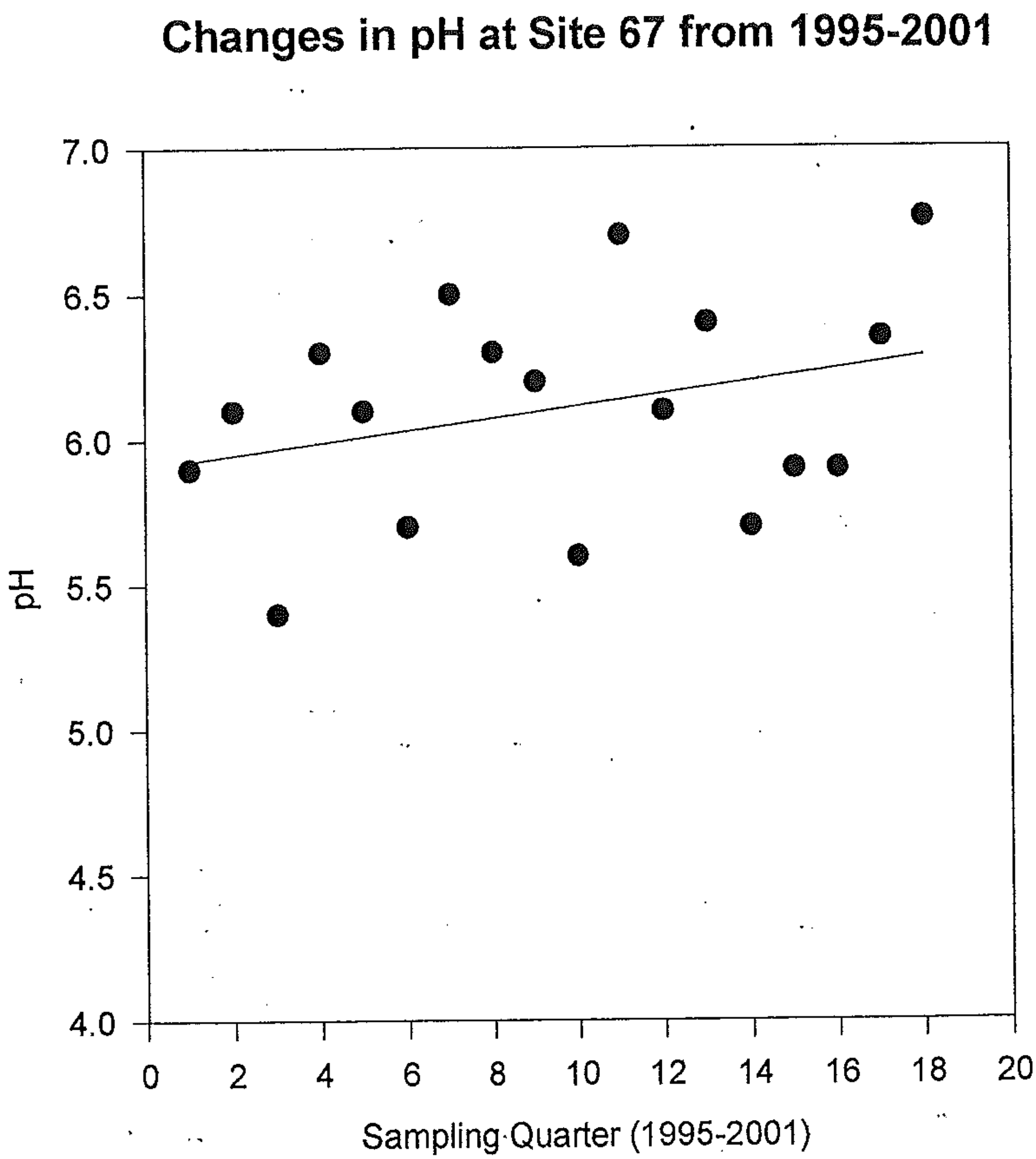

Changes in pH at Site 67 from 1995-2001
pH
7.0
6.5
6.0
5.5
5.0
4.5
4.0
0
2
4
6
8
10
12
14
16
18
20
Sampling Quarter (1995-2001)

Figure 8

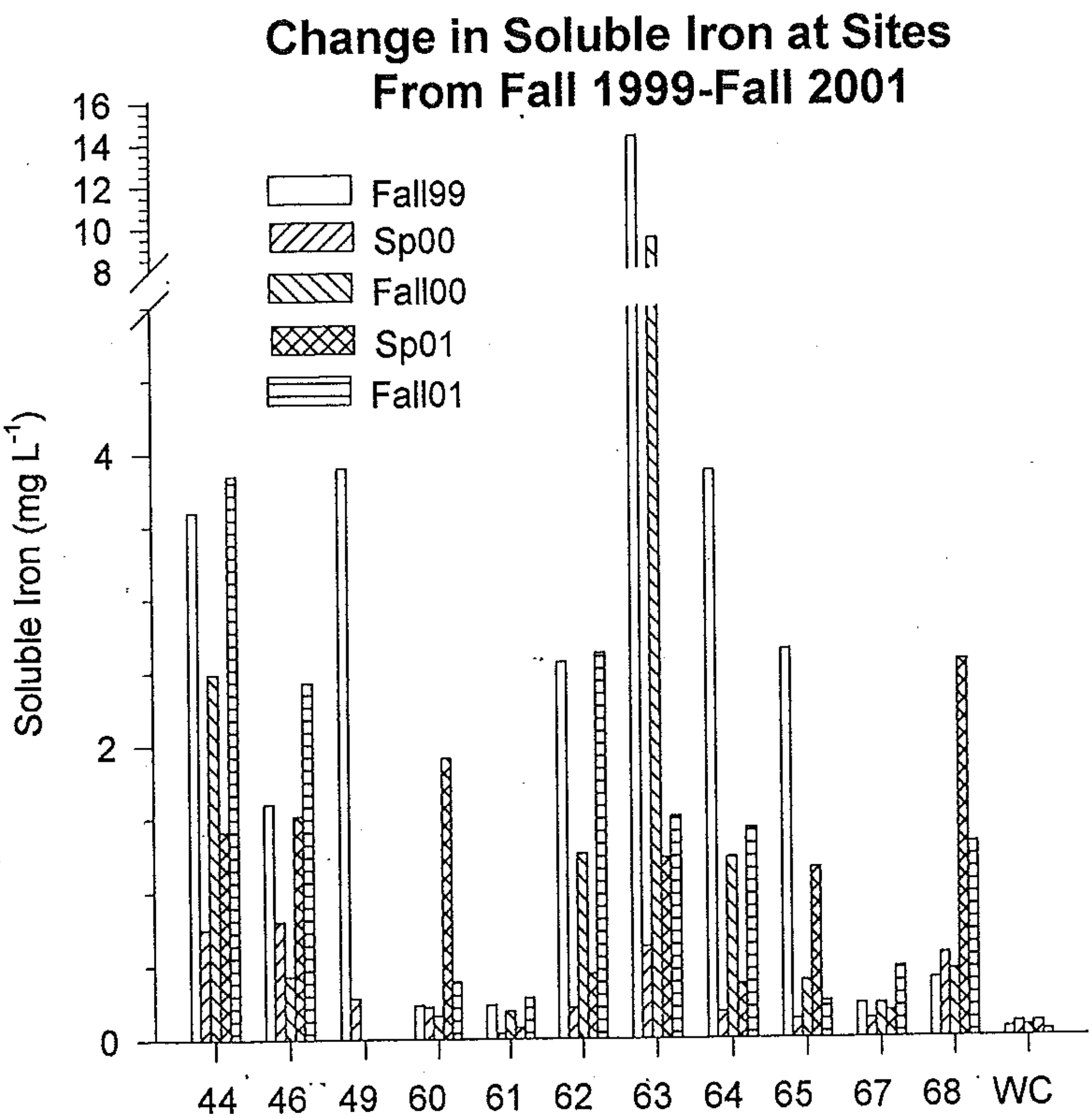

Change in Soluble Iron at Sites
From Fall 1999-Fall 2001
Soluble Iron (mg L-1)
16
14
12
10
8
4
2
0
Fall99
Sp00
Fall00
Sp01
Fall01
44
46
49
60
61
62
63
64
65
67
68
WC

Figure 10

Changes in Soluble Fe at Site 65 from 1995-2001

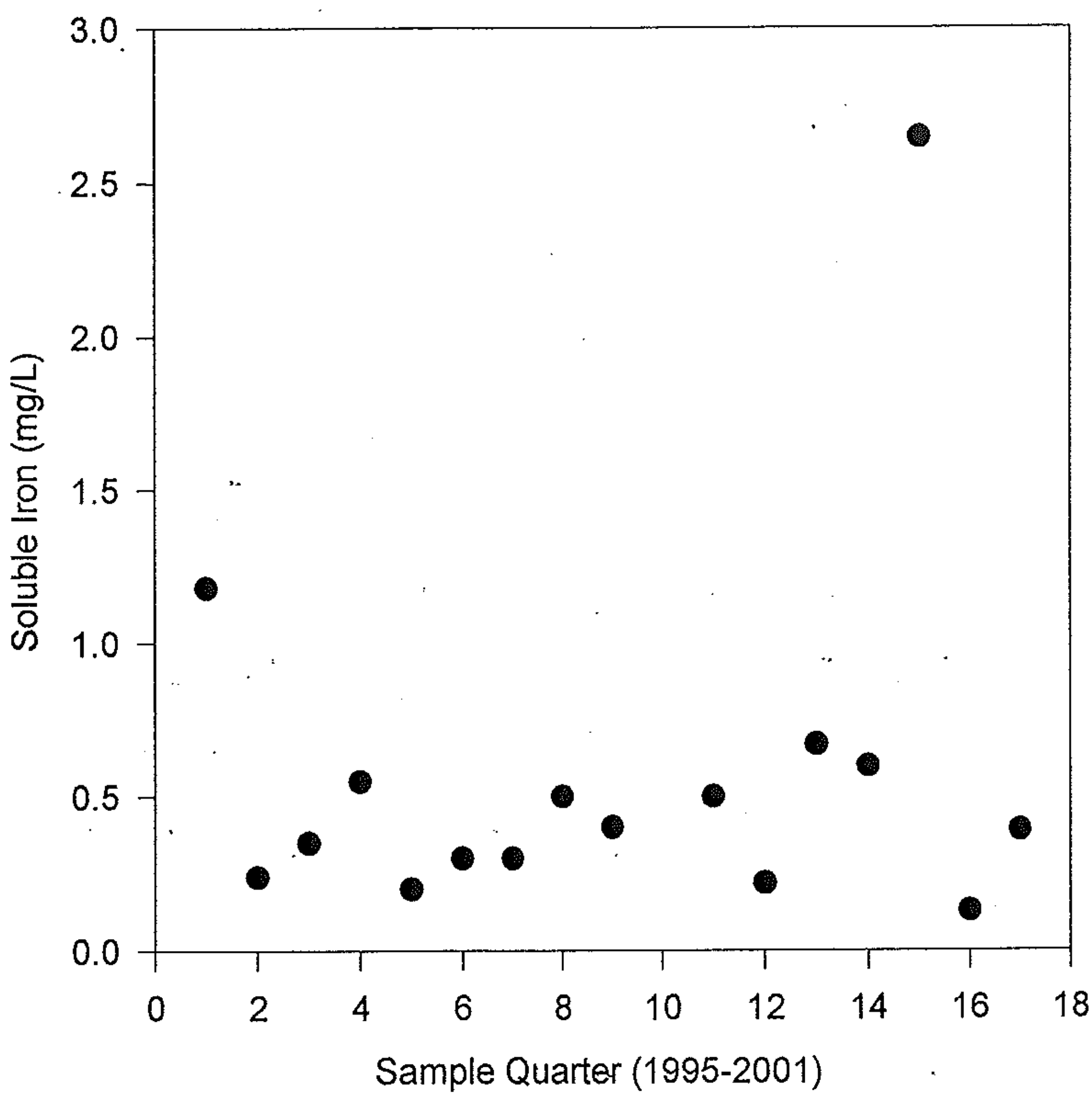


Figure 12

Change in Alkalinity with Discharge at Site 60

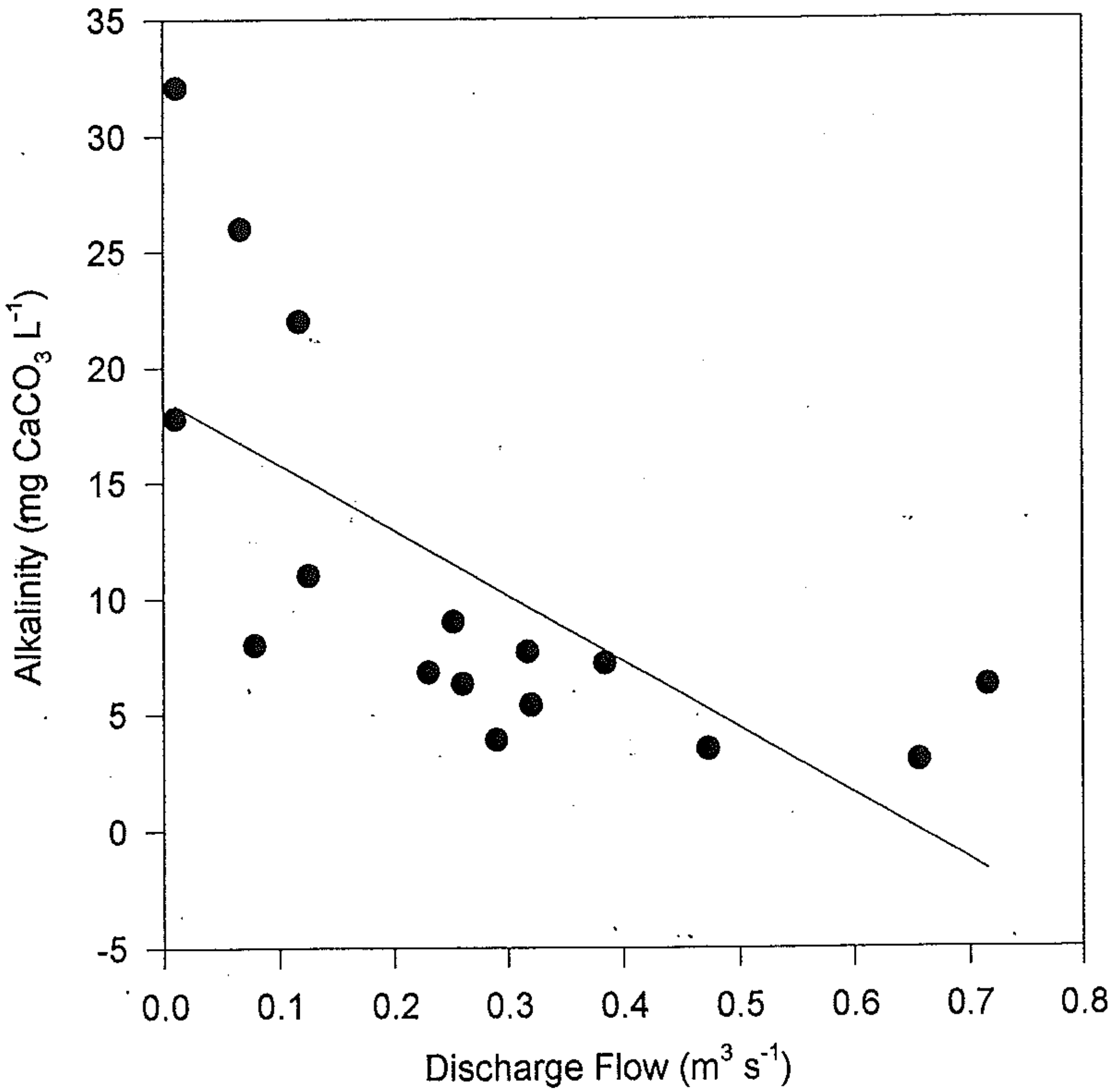


Figure 14

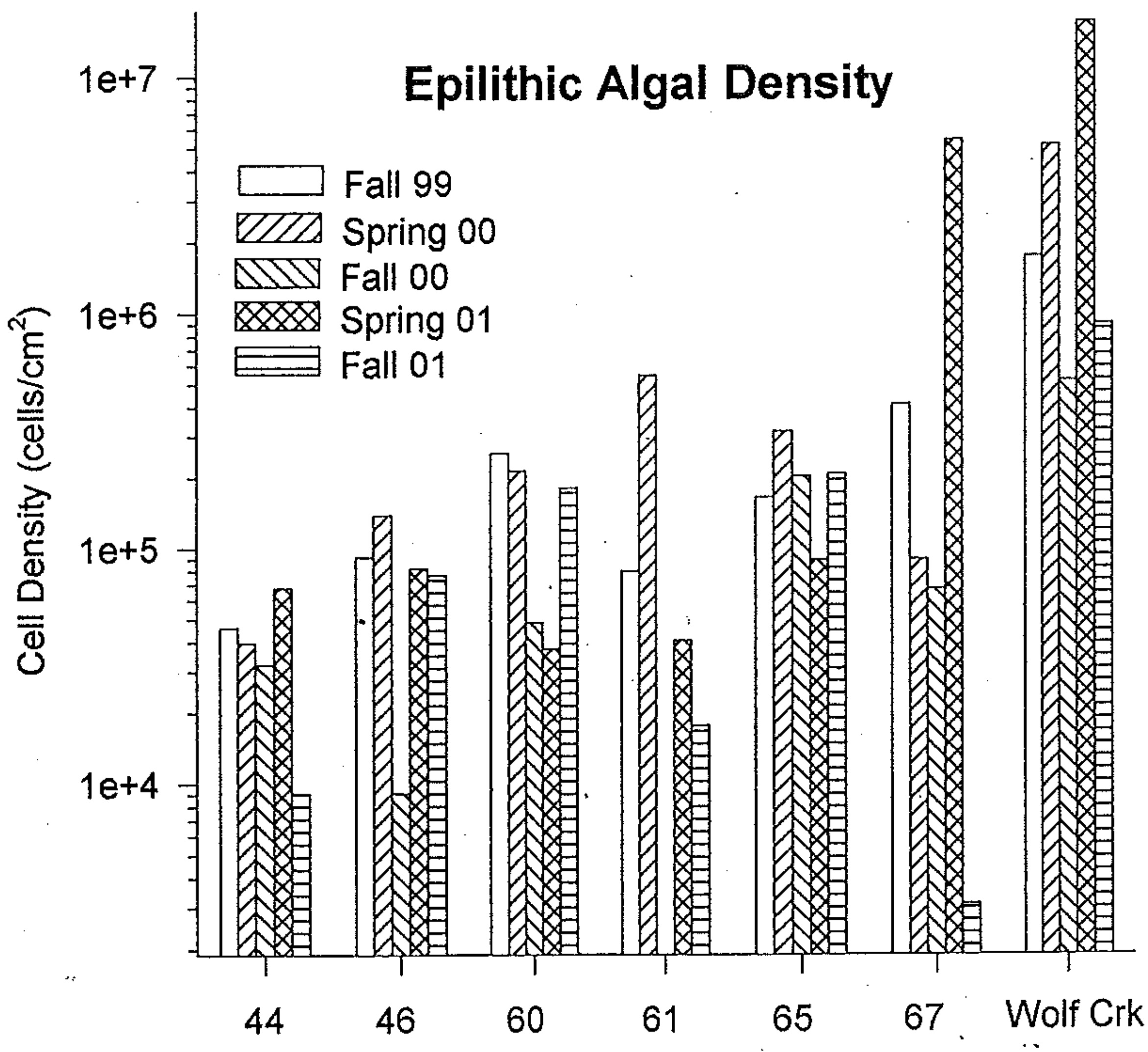

Epilithic Algal Density
Cell Density (cells/cm2)
1e+7
1e+6
1e+5
1e+4
Fall 99
Spring 00
Fall 00
Spring 01
Fall 01
44
46
60
61
65
67
Wolf Crk

Figure 16

Species Richness for Epilithic Algae

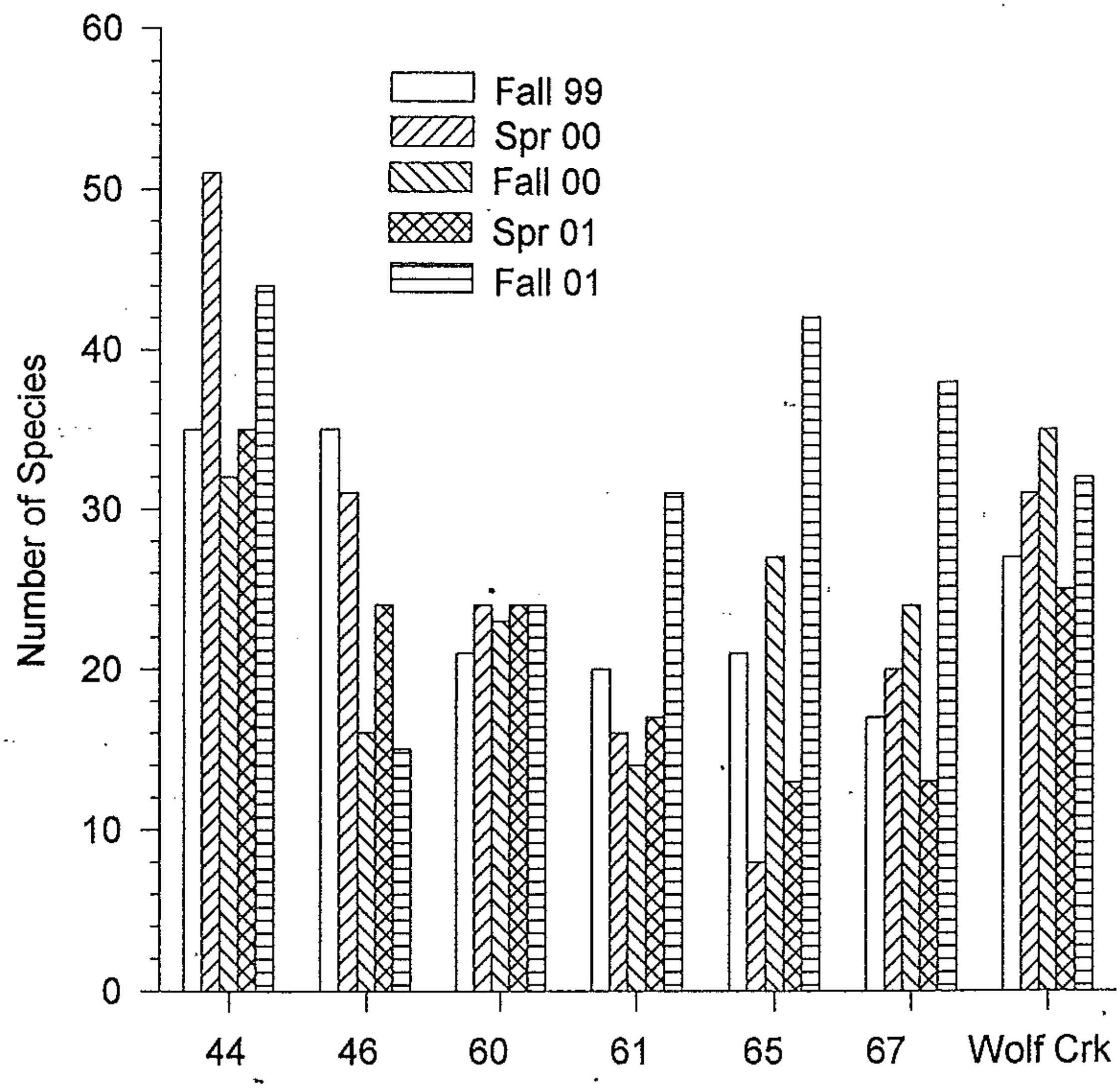


Figure 18

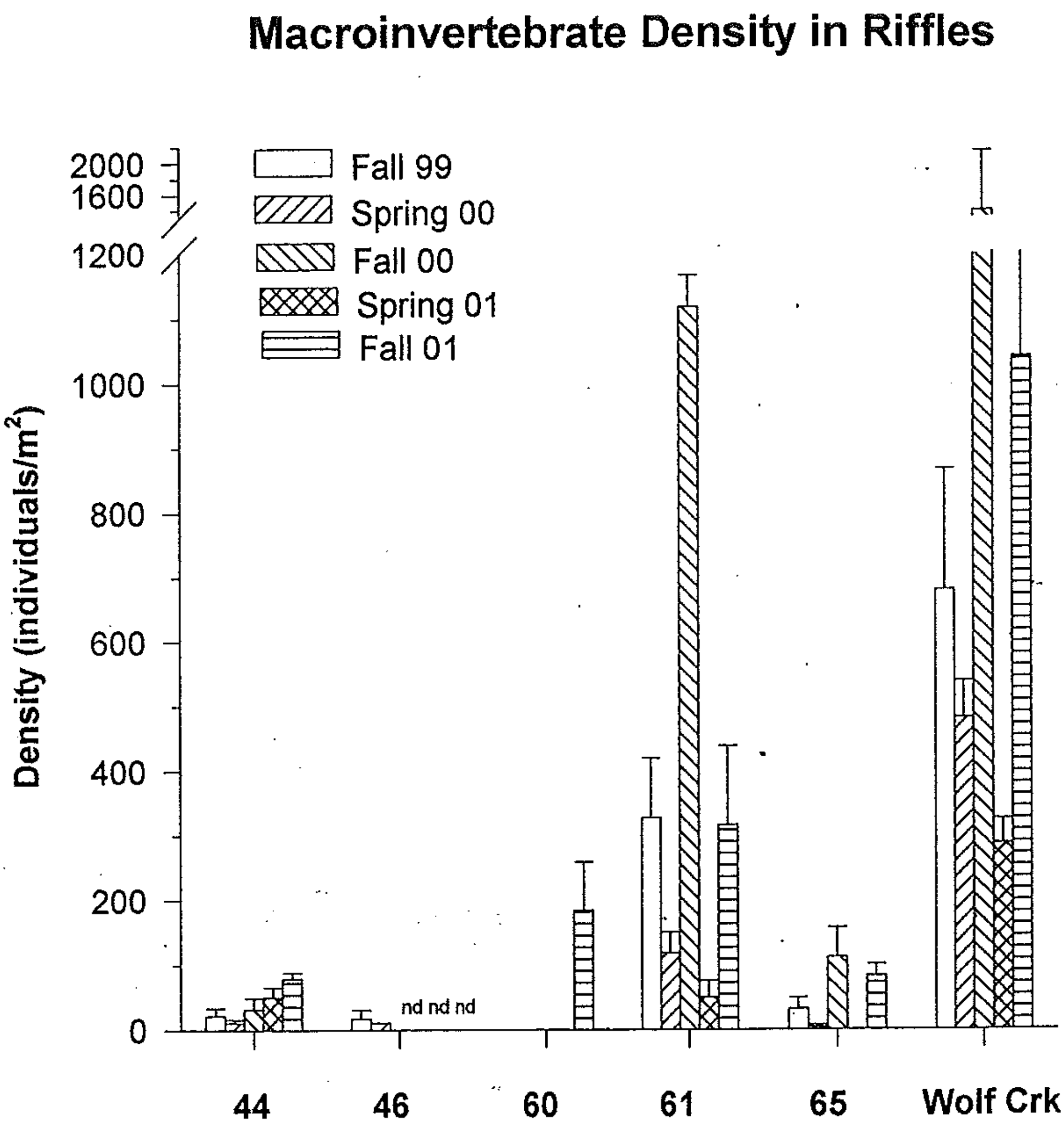

Macroinvertebrate Density in Riffles
Density (individuals/m²)
2000
1600
1200
1000
800
600
400
200
0
Fall 99
Spring 00
Fall 00
Spring 01
Fall 01
nd nd nd
44
46
60
61
65
Wolf Crk

Figure 20

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
Eun bilunaris	269
Eun curvata	240
Eun curvata v. capitata	319
Eun elegans	241
Eun exigua	238
Eun implicata	268
Eun intermedia	267
Eun musicola triden	270
Eun negelii	239
Eun sp.	318
Eun tenella	243
Eun vanherk	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 constr v venter	119
Frag lepto	117
Frag pinata NV	229
Frag pinnata v. lancetula	175
Frag sp	116
Frag vaucheriae	176
Frag virescens	262
Frust rhomb viridula	274
Frust rhomb. v. amphi	316
Frust rhomboides	177
Frust vulg crass	263
Frust weinholdii	302
Gomp acuminatum	120
Gomp afine	227
Gomp angustatum	122
Gomp constriuctum v capitata	123
Gomp gracile	228
Gomp olivacium	230
Gomp parvulum	121
Gomp sp.	178
Gomp subclavicum	179
Gomp. GV	352
Gongostonium	350
Gryosigma spencerii	180
Gyro modiferum	282
Hantz. amphioxys	359
Kirchneriella?	124
Klebsormidium	312
Melosira distans	258
Melosira islandica	220
Melosira varians	125
Meridon circulare	259
Merismopedia	335
Microspora	327
Mougeotia	339
Nav ?schoreder	323
Nav accomoda	211
Nav agphuphala??	317
Nav arvensis	133
Nav capitata	181
Nav celmintis	131
Nav cryptocephala NV	135
Nav cryptocephala venter	134
Nav crytotenella	265

Nitz sp.	201
Nitz sublinearis	298
Nitz. accuminata	347
Nitz. clausii	373
Nitz. dubia	301
Nitz. intermedia	360
Nitz. lencensis?	367
Nitz. obstusa	371
Nitz. perminuta	353
Nodularia	357
Odeogonium	316
Oocystis	333
Opephora martyi	146
Orthoseria roeseana	288
Oscillatoria	147
Pediastrum	201
PGV	305
Phormidium	148
Pinn abaujensis	318
Pinn braunii	321
Pinn caudata	225
Pinn dactylus	246
Pinn divergentissima	291
Pinn mesopleta	254
Pinn microstauron	248
Pinn obscura	249
Pinn sp	253
Pinn subcapitata	247
Pinn. divergens	309
Pinn. GV	358
Pinn. pseudomicrostauron	325
Pinn. subcapitata v. subog	344
Plectorina??	372
Rhoc cruvata	149
Scen bijuga	202
Scen incrasulatus	203
Scen obliquis	150
Scen quadicaudata	204
Scendesmus sp.	378
Sprulina	340
Staur phonecentron	282
Staur smithii	283
Stauroneis anceps	290
Stauroneis kregerii	281
Stig basal cells	152
Stig filament	153
Sur. patella	330
Suri angust	278
Suri linearis	223
Suri minuta	277
Suri ovallis	299
Suri ovata	205
Suriella amphioxys	304
Suriella brebisooni v. kut	342
Suriella sp	329
Symploca	363
Syn radians	351
Syn. puchella lanceolata	310
Synd acus	226
Synd rumpens or rumpens v. familaris	206
Synd tenera	221
Synd ulna	207
Tab flocculosa	244
Tribonema	341
Unknown green	154
Wollea	313

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

Date: 26 Feb 2002

Table I. Data and Summary Statistics

Original Sample Units

Label	99FL44	99FL46	99FL60	99FL61	99FL65	99FL67	99FLWC	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	0.0011	0.0000	0.0000	0.0000	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	0.0000	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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0043
111	0.0000	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	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	0.0000	0.0000	0.0000	0.0033	0.0000	0.0000	0.0000
127	0.0000	0.0000	0.0000	0.0000	0.0028	0.0000	0.0000	0.0006	0.0000	0.0000
128	0.0000	0.0032	0.0000	0.0000	0.0056	0.0056	0.0265	0.0017	0.0000	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	0.0000	0.0000	0.0000
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	0.0000	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	0.0000	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	0.0000	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	0.0000	0.0000
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	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	0.0000	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

255	0.0000	0.0000	0.0000	0.0010	0.0000	0.0000	0.0000	0.0006	0.0000	0.0000
256	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
259	0.0011	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0023	0.0000	0.0000
260	0.0034	0.0032	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0000
262	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0020	0.0000	0.0000
263	0.0288	0.0189	0.0000	0.0005	0.0000	0.0000	0.0000	0.0113	0.0000	0.0000
265	0.0000	0.0000	0.0024	0.0000	0.0000	0.0000	0.0828	0.0006	0.0000	0.0000
270	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000
271	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
275	0.0011	0.0063	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
276	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0017	0.0000	0.0000
277	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0027	0.0000
278	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0000
280	0.0101	0.0410	0.0098	0.0000	0.0028	0.0000	0.0000	0.0000	0.0090	0.0000
282	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
283	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
285	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
286	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
289	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0000
290	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
291	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
292	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
293	0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0100	0.0017	0.0018	0.0000
295	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
299	0.0000	0.0000	0.0000	0.0000	0.0028	0.0000	0.0000	0.0000	0.0000	0.0000
304	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
305	0.0034	0.0032	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0018	0.0000
308	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
309	0.0034	0.0000	0.0024	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
320	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
327	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
329	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0000	0.0000
330	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0000
346	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
348	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
369	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
371	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
373	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
379	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
389	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
403	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000
425	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
427	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
429	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
430	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
431	0.0000	0.0032	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
432	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0000	0.0000	0.0000	0.0000
433	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
442	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
454	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table I. Data and Summary Statistics

Original Sample Units

Label	00SP61	00SP65	00SP67	00SPWC	00FL44	00FL46	00FL60	00FL61	00FL65	00FL67
Totals	99.97	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	0.0000	0.0000	0.0000	0.0000
102	0.0525	0.8700	0.5683	0.0837	0.0104	0.5614	0.1331	0.6593	0.2363	0.3367
107	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
109	0.0000	0.0000	0.0000	0.1513	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
110	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
111	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	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	0.0000	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	0.0000	0.0077
120	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	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	0.0000	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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
137	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	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	0.0000	0.0000	0.0000	0.0009	0.0000	0.0036	0.0000	0.0259	0.0000
142	0.0000	0.0000	0.0000	0.0644	0.0005	0.0043	0.0000	0.0052	0.0000	0.0000
144	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
147	0.0412	0.0030	0.0070	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
148	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	0.0000	0.0000	0.0000	0.0070	0.0000	0.0000	0.0050	0.0000	0.0000	0.0000
153	0.1941	0.0000	0.0070	0.0000	0.0110	0.0000	0.0000	0.0000	0.0000	0.0000
154	0.0000	0.0000	0.0000	0.0211	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
160	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

255	0.0000	0.0000	0.0000	0.0128	0.0000	0.0043	0.0071	0.0000	0.0000	0.0000
256	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
259	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
260	0.0000	0.0000	0.0000	0.0000	0.0005	0.0043	0.0000	0.0000	0.0000	0.0000
262	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
263	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
265	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
270	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
271	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
275	0.0000	0.0000	0.0000	0.0000	0.0009	0.0000	0.0000	0.0000	0.0032	0.0000
276	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
277	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
278	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
280	0.0000	0.0065	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
282	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0065	0.0000
283	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0052	0.0000	0.0000
285	0.0000	0.0000	0.0000	0.0000	0.0035	0.0043	0.0710	0.0000	0.0000	0.0046
286	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
289	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
290	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
291	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000
292	0.0000	0.0000	0.0000	0.0000	0.0000	0.0022	0.0000	0.0000	0.0000	0.0000
293	0.0000	0.0000	0.0000	0.0128	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
295	0.0000	0.0000	0.0000	0.0064	0.0000	0.0000	0.0000	0.0000	0.0000	0.0031
299	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
304	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0065	0.0015
305	0.0000	0.0000	0.0000	0.0128	0.0014	0.0000	0.0071	0.0052	0.0129	0.0000
308	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
309	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
320	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000
327	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
329	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
330	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
346	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0018	0.0000	0.0000	0.0000
348	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
369	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
371	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
373	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
379	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0065	0.0000
389	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
403	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
425	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
427	0.0000	0.0000	0.0000	0.0096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
429	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0036	0.0000	0.0000	0.0000
430	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
431	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
432	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0680	0.0000
433	0.0000	0.0000	0.0000	0.0064	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
442	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
454	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table I. Data and Summary Statistics

Original Sample Units

Label	00FLWC	01SP44	01SP46	01SP60	01SP61	01SP65	01SP67	01SPWC	01FL44	01FL46
Totals	100.11	99.99	99.95	100.01	99.00	99.93	99.99	100.03	99.96	100.01
Species ID										
100	0.0195	0.0097	0.0000	0.0000	0.0027	0.0000	0.0000	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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
109	0.1105	0.0097	0.0000	0.0000	0.0000	0.0000	0.0000	0.0516	0.0000	0.0000
110	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
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	0.0000	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	0.0000	0.0000	0.0000	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	0.0000
128	0.0000	0.0048	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	0.0041	0.0000
135	0.0098	0.0000	0.0000	0.0132	0.0000	0.0000	0.0000	0.0000	0.0041	0.0058
136	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
137	0.0130	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0129	0.0041	0.0000
139	0.0098	0.0000	0.0060	0.0066	0.0000	0.0000	0.0000	0.0000	0.0041	0.0000
140	0.0098	0.0145	0.0000	0.0000	0.0000	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	0.0000	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	0.0000	0.0000	0.0000	0.0000	0.0455	0.0000	0.0000	0.0000	0.0090	0.0000
154	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
160	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0000
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	0.0000	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
169	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

255	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
256	0.0000	0.0097	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0041	0.0000
259	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0041	0.0000
260	0.0065	0.0193	0.0000	0.0066	0.0000	0.0000	0.0000	0.0000	0.0021	0.0058
262	0.0000	0.0435	0.0000	0.0000	0.0056	0.0000	0.0000	0.0000	0.0000	0.0000
263	0.0000	0.0000	0.0060	0.0000	0.0000	0.0000	0.0000	0.0000	0.0041	0.0000
265	0.0942	0.0097	0.0000	0.0000	0.0000	0.0000	0.0056	0.0290	0.0000	0.0029
270	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
271	0.0000	0.0000	0.0060	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
275	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0062	0.0000
276	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
277	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
278	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
280	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
282	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0032	0.0000	0.0000
283	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
285	0.0000	0.0048	0.0000	0.0132	0.0000	0.0000	0.0000	0.0000	0.0144	0.0058
286	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
289	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
290	0.0000	0.0000	0.0000	0.0066	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
291	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
292	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
293	0.0065	0.0048	0.0000	0.0000	0.0000	0.0000	0.0000	0.0419	0.0000	0.0000
295	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
299	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
304	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
305	0.0065	0.0193	0.0120	0.0066	0.0000	0.0115	0.0000	0.0000	0.0000	0.0058
308	0.0000	0.0097	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
309	0.0000	0.0097	0.0030	0.0132	0.0000	0.0000	0.0000	0.0000	0.0082	0.0000
320	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
327	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
329	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
330	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
346	0.0000	0.0000	0.0000	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
348	0.0000	0.0000	0.0000	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
369	0.0942	0.0386	0.0000	0.0000	0.0000	0.0000	0.0000	0.0032	0.0041	0.0000
371	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0041	0.0000
373	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
379	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
389	0.0000	0.0000	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
403	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
425	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
427	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
429	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
430	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0065	0.0000	0.0000
431	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
432	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
433	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
442	0.0000	0.0000	0.0000	0.0066	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
454	0.0000	0.0000	0.0000	0.0000	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000

Table I. Data and Summary Statistics

Original Sample Units

Label	01FL60	01FL61	01FL65	01FL67	01FLWC
Totals	99.99	101.22	99.93	100.08	100.01
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	0.0329
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	0.0000
119	0.0000	0.0000	0.0000	0.0971	0.0033
120	0.0000	0.0056	0.0000	0.0056	0.0000
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	0.0000	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	0.0000
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
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	0.0000	0.0000	0.0000	0.0000
154	0.0000	0.0000	0.0000	0.0000	0.0000
160	0.0000	0.0000	0.0000	0.0000	0.0033
162	0.0000	0.0000	0.0000	0.0056	0.0033
165	0.0000	0.0000	0.0000	0.0000	0.0000
167	0.0000	0.0000	0.0030	0.0028	0.0000
169	0.0000	0.0000	0.0000	0.0000	0.0000

255	0.0000	0.0000	0.0000	0.0000	0.0066
256	0.0000	0.0000	0.0000	0.0000	0.0000
259	0.0000	0.0000	0.0000	0.0000	0.0000
260	0.0000	0.0000	0.0119	0.0000	0.0000
262	0.0000	0.0056	0.0000	0.0000	0.0000
263	0.0000	0.0252	0.0000	0.0000	0.0000
265	0.0149	0.0112	0.0000	0.0000	0.0197
270	0.0000	0.0000	0.0000	0.0000	0.0000
271	0.0000	0.0000	0.0000	0.0000	0.0000
275	0.0000	0.0168	0.0059	0.0028	0.0000
276	0.0000	0.0000	0.0000	0.0000	0.0000
277	0.0000	0.0028	0.0000	0.0000	0.0000
278	0.0000	0.0000	0.0059	0.0000	0.0000
280	0.0000	0.0000	0.0267	0.0000	0.0000
282	0.0000	0.0000	0.0000	0.0000	0.0000
283	0.0000	0.0028	0.0000	0.0000	0.0000
285	0.0386	0.0000	0.0504	0.0111	0.0000
286	0.0000	0.0000	0.0000	0.0000	0.0000
289	0.0000	0.0000	0.0000	0.0000	0.0000
290	0.0000	0.0000	0.0000	0.0000	0.0000
291	0.0000	0.0000	0.0000	0.0000	0.0000
292	0.0000	0.0000	0.0000	0.0000	0.0000
293	0.0000	0.0000	0.0000	0.0000	0.0033
295	0.0000	0.0000	0.0000	0.0000	0.0000
299	0.0000	0.0000	0.0059	0.0000	0.0000
304	0.0000	0.0000	0.0000	0.0000	0.0000
305	0.0208	0.0365	0.0237	0.0250	0.0000
308	0.0000	0.0000	0.0000	0.0000	0.0000
309	0.0000	0.0000	0.0000	0.0000	0.0000
320	0.0000	0.0000	0.0000	0.0000	0.0000
327	0.0240	0.0000	0.0060	0.0000	0.0000
329	0.0000	0.0000	0.0000	0.0000	0.0000
330	0.0000	0.0000	0.0000	0.0000	0.0000
346	0.0000	0.0000	0.0000	0.0000	0.0000
348	0.0000	0.0000	0.0000	0.0000	0.0000
369	0.0000	0.0000	0.0326	0.0000	0.0394
371	0.0000	0.0000	0.0000	0.0000	0.0000
373	0.0000	0.0392	0.0000	0.0000	0.0000
379	0.0000	0.0000	0.0000	0.0000	0.0000
389	0.0000	0.0000	0.0119	0.0056	0.0000
403	0.0000	0.0000	0.0000	0.0000	0.0000
425	0.0000	0.0000	0.0059	0.0028	0.0000
427	0.0000	0.0000	0.0059	0.0000	0.0000
429	0.0000	0.0000	0.0000	0.0000	0.0000
430	0.0000	0.0000	0.0000	0.0000	0.0000
431	0.0000	0.0000	0.0000	0.0000	0.0000
432	0.0000	0.0000	0.0326	0.0111	0.0000
433	0.0000	0.0000	0.0000	0.0000	0.0000
442	0.0000	0.0000	0.0000	0.0000	0.0000
454	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix IC

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

Date: 27 Feb 2002

Table I. Data and Summary Statistics

Original Sample Units

Label	99FL44	99FL46	99FL60	99FL61	99FL65	99FL67	99FLWC	00SP44	00SP46	00FL60
Totals	99.98	99.95	99.97	99.97	99.95	99.99	99.98	103.09	99.95	99.98
Species ID										
100	0.0010	0.0000	0.0000	0.0040	0.0000	0.0000	0.0322	0.0097	0.0018	0.0383
102	0.0131	0.0303	0.0506	0.0356	0.0965	0.1474	0.0161	0.1295	0.0568	0.2107
107	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
108	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0161	0.0000	0.0000	0.0000
109	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0354	0.0000	0.0000	0.0000
110	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
111	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0079
113	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
115	0.0010	0.0177	0.0891	0.0085	0.0296	0.0855	0.0000	0.0078	0.0253	0.1615
119	0.0000	0.0000	0.0000	0.0000	0.0000	0.0501	0.0064	0.0000	0.0000	0.0137
120	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
121	0.0044	0.0177	0.0000	0.0022	0.0473	0.0413	0.0193	0.0541	0.0207	0.0137
122	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0064	0.0000	0.0000	0.0000
125	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
128	0.0000	0.0000	0.0000	0.0013	0.0020	0.0000	0.0000	0.0019	0.0018	0.0000
130	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
131	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
132	0.0000	0.0000	0.0000	0.0000	0.0039	0.0118	0.0000	0.0000	0.0000	0.0000
133	0.0000	0.0050	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0055
135	0.0003	0.0379	0.0000	0.0018	0.0118	0.0531	0.0611	0.0058	0.0018	0.0000
136	0.0000	0.0000	0.0000	0.0000	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000
137	0.0000	0.0000	0.0000	0.0000	0.0020	0.0000	0.0129	0.0000	0.0000	0.0000
139	0.0000	0.0000	0.0048	0.0009	0.0039	0.0000	0.0064	0.0000	0.0018	0.0109
140	0.0064	0.0909	0.0410	0.0098	0.0571	0.0855	0.0707	0.0097	0.0036	0.0109
141	0.0000	0.0101	0.0000	0.0000	0.0118	0.0442	0.0064	0.0000	0.0000	0.0000
142	0.0003	0.0303	0.0000	0.0000	0.0276	0.0236	0.0354	0.0290	0.0009	0.0000
147	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
148	0.9276	0.2401	0.2772	0.8532	0.3992	0.1008	0.0000	0.4158	0.5211	0.0000
149	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0096	0.0000	0.0000	0.0000
150	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
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	0.0157
163	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0064	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

251	0.0000	0.0000	0.0434	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0027
253	0.0000	0.0000	0.0000	0.0000	0.0039	0.0000	0.0000	0.0039	0.0018	0.0055
254	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0063	0.0000
255	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
256	0.0013	0.0000	0.0000	0.0009	0.0000	0.0000	0.0000	0.0232	0.0000	0.0055
259	0.0003	0.0000	0.0000	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0055
260	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0212	0.0036	0.0000
262	0.0000	0.0000	0.0000	0.0058	0.0000	0.0000	0.0000	0.0039	0.0000	0.0000
263	0.0000	0.1743	0.0000	0.0058	0.0000	0.0029	0.0000	0.0309	0.0117	0.0000
265	0.0000	0.0000	0.0000	0.0000	0.0000	0.0118	0.0257	0.0039	0.0000	0.0000
270	0.0000	0.0050	0.0000	0.0000	0.0000	0.0000	0.0000	0.0058	0.0000	0.0000
271	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0055
275	0.0013	0.0050	0.0000	0.0000	0.0039	0.0000	0.0000	0.0000	0.0000	0.0000
276	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
277	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0064	0.0000	0.0000	0.0000
278	0.0000	0.0000	0.0000	0.0013	0.0000	0.0059	0.0000	0.0058	0.0000	0.0000
280	0.0007	0.0984	0.0000	0.0018	0.0000	0.0206	0.0000	0.0000	0.0036	0.0000
282	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0032	0.0000	0.0000	0.0000
283	0.0000	0.0000	0.0000	0.0107	0.0000	0.0059	0.0000	0.0039	0.0000	0.0000
285	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0036	0.0000
289	0.0007	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0078	0.0009	0.0000
290	0.0003	0.0000	0.0000	0.0000	0.0000	0.0029	0.0000	0.0058	0.0000	0.0000
291	0.0007	0.0050	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0018	0.0000
293	0.0000	0.0025	0.0096	0.0000	0.0079	0.0059	0.0193	0.0039	0.0000	0.0055
295	0.0000	0.0000	0.0000	0.0152	0.0000	0.0029	0.0000	0.0039	0.0018	0.0000
299	0.0000	0.0000	0.0000	0.0000	0.0039	0.0000	0.0000	0.0000	0.0000	0.0000
301	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
304	0.0000	0.0000	0.0048	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
305	0.0013	0.0202	0.0000	0.0062	0.0118	0.0531	0.0129	0.0078	0.0018	0.0164
308	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019	0.0000	0.0000
309	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
313	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
316	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
320	0.0000	0.0000	0.0000	0.0000	0.0000	0.0059	0.0064	0.0000	0.0000	0.0000
329	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0039	0.0000	0.0000
332	0.0000	0.0000	0.0000	0.0000	0.0000	0.0059	0.0000	0.0000	0.0000	0.0000
335	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
342	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
347	0.0000	0.0000	0.0000	0.0000	0.0000	0.0177	0.0000	0.0000	0.0000	0.0000
349	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
359	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2084	0.0000
369	0.0000	0.0000	0.0000	0.0000	0.0039	0.0000	0.0225	0.0039	0.0000	0.0000
371	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
373	0.0000	0.0025	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019	0.0000	0.0000
388	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
389	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
403	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0039	0.0000	0.0000
427	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
431	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0064	0.0000	0.0000	0.0000
432	0.0000	0.0000	0.0000	0.0000	0.0079	0.0000	0.0000	0.0000	0.0000	0.0000

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

Table I. Data and Summary Statistics

Original Sample Units

Label	00SP61	00SP65	00SP67	00SPWC	00FL44	00FL46	00FL60	00FL61	00FL65	00FL67
Totals	99.96	99.35	99.99	99.97	100.76	99.99	99.98	100.04	99.98	100.02
Species ID										
100	0.0078	0.0063	0.0000	0.0133	0.0036	0.0000	0.0000	0.0146	0.0134	0.0000
102	0.2617	0.1182	0.3671	0.0266	0.0205	0.2069	0.1412	0.1019	0.1276	0.1297
107	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
108	0.0000	0.0000	0.0112	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0203
109	0.0000	0.0000	0.0000	0.0498	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
110	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
111	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	0.0000	0.0000	0.0000
115	0.0235	0.1469	0.1345	0.0000	0.0018	0.1910	0.0927	0.0680	0.0672	0.0486
119	0.0000	0.0191	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	0.0203
122	0.0209	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
125	0.0000	0.0000	0.0000	0.0266	0.0000	0.0000	0.0000	0.0000	0.0067	0.0000
127	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
128	0.0130	0.0063	0.0000	0.0199	0.0054	0.0159	0.0000	0.0000	0.0000	0.0000
130	0.0026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
131	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0097	0.0000	0.0000
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	0.0000
136	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1013
137	0.0000	0.0000	0.0000	0.0133	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
139	0.0182	0.0063	0.0000	0.0000	0.0000	0.0000	0.0088	0.0000	0.0000	0.0000
140	0.0000	0.0543	0.0112	0.0797	0.0071	0.0796	0.0530	0.0146	0.0739	0.0081
141	0.0000	0.0063	0.0112	0.0000	0.0000	0.0000	0.0309	0.0000	0.0000	0.0892
142	0.0000	0.0063	0.0056	0.0465	0.0000	0.0000	0.0000	0.0097	0.0201	0.0081
147	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0064	0.0000	0.0000	0.0162
148	0.2044	0.0058	0.0377	0.0000	0.9098	0.1961	0.0892	0.4998	0.3001	0.0000
149	0.0000	0.0000	0.0000	0.0266	0.0000	0.0000	0.0000	0.0000	0.0000	0.0462
150	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
154	0.0108	0.0058	0.0189	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
160	0.0000	0.0000	0.0000	0.0133	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
163	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	0.0000	0.0000	0.0000	0.0000

251	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0441	0.0000	0.0000	0.0000
253	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
254	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0081
255	0.0104	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
256	0.0026	0.0000	0.0000	0.0000	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000
259	0.0026	0.0160	0.0000	0.0199	0.0000	0.0000	0.0000	0.0097	0.0000	0.0000
260	0.0000	0.0000	0.0056	0.0000	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000
262	0.0704	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0049	0.0000	0.0000
263	0.0000	0.0000	0.0000	0.0000	0.0009	0.0000	0.0309	0.0000	0.0000	0.0000
265	0.0000	0.0063	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
270	0.0000	0.0000	0.0000	0.0000	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000
271	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
275	0.0000	0.0128	0.0000	0.0000	0.0036	0.0000	0.0000	0.0000	0.0000	0.0000
276	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
277	0.0000	0.0000	0.0000	0.0066	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
278	0.0052	0.0096	0.0000	0.0000	0.0018	0.0000	0.0000	0.0000	0.0067	0.0000
280	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0067	0.0041
282	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
283	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0088	0.0000	0.0067	0.0000
285	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
289	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0049	0.0000	0.0000
290	0.0078	0.0000	0.0056	0.0000	0.0018	0.0080	0.0000	0.0049	0.0000	0.0000
291	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0097	0.0000	0.0000
293	0.0000	0.0063	0.0000	0.0100	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
295	0.0026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
299	0.0000	0.0000	0.0000	0.0066	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
301	0.0000	0.0000	0.0000	0.0000	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000
304	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
305	0.0104	0.0128	0.0168	0.0100	0.0000	0.0159	0.0000	0.0340	0.0067	0.0081
308	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
309	0.0000	0.0000	0.0000	0.0000	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000
313	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
316	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
320	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
329	0.0000	0.0000	0.0056	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
332	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
335	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
342	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
347	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
349	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
359	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
369	0.0000	0.0000	0.0000	0.0000	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000
371	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0081
373	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0097	0.0067	0.0000
388	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
389	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
403	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
427	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
431	0.0000	0.0000	0.0000	0.0133	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
432	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0101	0.0000

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

Table I. Data and Summary Statistics

Original Sample Units

Label	00FLWC	01SP44	01SP46	01SP60	01SP61	01SP65	01SP67	01SPWC	01FL44	01FL46
Totals	98.97	99.95	99.97	99.99	100.00	100.02	100.72	100.01	100.04	99.99
Species ID										
100	0.0389	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0164	0.0000	0.0032
102	0.0145	0.1315	0.1424	0.1350	0.1500	0.2325	0.4745	0.0329	0.0045	0.1132
107	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
108	0.0048	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0066	0.0000	0.0000
109	0.0730	0.0000	0.0000	0.0000	0.0000	0.0064	0.0000	0.0921	0.0000	0.0000
110	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
111	0.0194	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0099	0.0000	0.0000
113	0.0097	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0230	0.0000	0.0000
115	0.0000	0.0000	0.0271	0.1782	0.0150	0.0860	0.0698	0.0000	0.0011	0.0259
119	0.0389	0.0000	0.0000	0.0378	0.0000	0.0414	0.0930	0.0493	0.0000	0.0032
120	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
121	0.0097	0.1315	0.0407	0.0108	0.0450	0.0191	0.0093	0.0230	0.0011	0.0194
122	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
125	0.0097	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	0.0000	0.0000	0.0000	0.0000
128	0.0194	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
130	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
131	0.0145	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
132	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	0.0000	0.0000	0.0000	0.0000
135	0.0827	0.0057	0.0136	0.0054	0.0100	0.0064	0.0279	0.0197	0.0006	0.0873
136	0.0048	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
137	0.0097	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0164	0.0000	0.0000
139	0.0000	0.0000	0.0000	0.0054	0.0000	0.0064	0.0093	0.0132	0.0006	0.0000
140	0.0486	0.0171	0.0136	0.0081	0.0000	0.0319	0.0326	0.0427	0.0006	0.1585
141	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
142	0.0972	0.0000	0.0000	0.0000	0.0000	0.0255	0.0000	0.0756	0.0000	0.0000
147	0.0025	0.0357	0.0000	0.0000	0.0263	0.0222	0.0139	0.0000	0.0000	0.0033
148	0.0087	0.3573	0.2309	0.1519	0.4737	0.0222	0.0417	0.0041	0.9713	0.0232
149	0.0292	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0132	0.0000	0.0000
150	0.0000	0.0000	0.0000	0.0063	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
154	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
160	0.0341	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0033	0.0000	0.0000
163	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0139	0.0000	0.0000	0.0033
165	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	0.0054	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
253	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
254	0.0000	0.0057	0.0000	0.0108	0.0000	0.0064	0.0000	0.0000	0.0000	0.0000
255	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000
256	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
259	0.0000	0.0057	0.0000	0.0000	0.0250	0.0064	0.0000	0.0000	0.0008	0.0000
260	0.0097	0.0343	0.0000	0.0000	0.0000	0.0032	0.0047	0.0000	0.0020	0.0194
262	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0025	0.0000
263	0.0000	0.0000	0.0068	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
265	0.0097	0.0000	0.0000	0.0027	0.0000	0.0000	0.0047	0.0263	0.0000	0.0000
270	0.0000	0.0114	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
271	0.0000	0.0057	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
275	0.0244	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0065
276	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
277	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0263	0.0000	0.0000
278	0.0000	0.0000	0.0000	0.0000	0.0000	0.0159	0.0000	0.0000	0.0006	0.0000
280	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
282	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
283	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
285	0.0000	0.0000	0.0000	0.0000	0.0000	0.0064	0.0000	0.0000	0.0000	0.0259
289	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
290	0.0000	0.0000	0.0000	0.0081	0.0050	0.0000	0.0047	0.0000	0.0000	0.0000
291	0.0000	0.0057	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0017	0.0000
293	0.0097	0.0000	0.0136	0.0000	0.0000	0.0000	0.0000	0.0066	0.0000	0.0065
295	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
299	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0097
301	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
304	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
305	0.0097	0.0171	0.0678	0.0081	0.0000	0.0223	0.0140	0.0066	0.0014	0.0873
308	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
309	0.0000	0.0114	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
313	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
316	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
320	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
329	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
332	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
335	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
342	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
347	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
349	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0041	0.0000	0.0000
359	0.0000	0.0000	0.0068	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
369	0.0194	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000
371	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
373	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
388	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0066	0.0000	0.0000
389	0.0000	0.0000	0.0136	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000	0.0065
403	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
427	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0066	0.0011	0.0000
431	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
432	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table I. Data and Summary Statistics

Original Sample Units

Label	01FL60	01FL61	01FL65	01FLWC
Totals	99.97	100.05	99.50	99.93
Species ID				
100	0.0000	0.0246	0.0128	0.0379
102	0.2338	0.0663	0.1945	0.0063
107	0.0109	0.0038	0.0128	0.0506
108	0.0000	0.0000	0.0000	0.0000
109	0.0000	0.0000	0.0000	0.0506
110	0.0000	0.0000	0.0000	0.0000
111	0.0000	0.0000	0.0000	0.0285
113	0.0000	0.0000	0.0063	0.0190
115	0.0544	0.0303	0.0542	0.0063
119	0.0000	0.0000	0.0446	0.0221
120	0.0027	0.0000	0.0000	0.0000
121	0.0163	0.0227	0.0095	0.0063
122	0.0000	0.0076	0.0000	0.0000
125	0.0000	0.0000	0.0000	0.0664
127	0.0000	0.0000	0.0000	0.0000
128	0.0000	0.0000	0.0000	0.0000
130	0.0000	0.0000	0.0000	0.0000
131	0.0000	0.0000	0.0000	0.0000
132	0.0000	0.0000	0.0000	0.0000
133	0.0000	0.0019	0.0128	0.0063
135	0.0190	0.0000	0.0510	0.1013
136	0.0000	0.0000	0.0000	0.0000
137	0.0000	0.0000	0.0000	0.0095
139	0.0000	0.0000	0.0000	0.0063
140	0.0054	0.0038	0.0957	0.0379
141	0.0054	0.0000	0.0000	0.0063
142	0.0000	0.0000	0.0063	0.0379
147	0.0190	0.0000	0.0044	0.0000
148	0.1103	0.5603	0.0398	0.0202
149	0.0000	0.0000	0.0032	0.0379
150	0.0076	0.0000	0.0000	0.0000
154	0.0000	0.0455	0.0000	0.0000
160	0.0000	0.0000	0.0000	0.0095
163	0.0000	0.0000	0.0000	0.0040
165	0.0076	0.0000	0.0000	0.0000

251	0.0000	0.0000	0.0000	0.0000
253	0.0000	0.0000	0.0000	0.0000
254	0.0027	0.0000	0.0063	0.0000
255	0.0000	0.0000	0.0000	0.0000
256	0.0000	0.0038	0.0000	0.0000
259	0.0000	0.0133	0.0063	0.0000
260	0.0000	0.0057	0.0000	0.0000
262	0.0000	0.0057	0.0000	0.0000
263	0.0000	0.0133	0.0032	0.0000
265	0.0000	0.0000	0.0063	0.0126
270	0.0000	0.0076	0.0000	0.0000
271	0.0000	0.0000	0.0000	0.0000
275	0.0000	0.0019	0.0478	0.0000
276	0.0000	0.0000	0.0000	0.0063
277	0.0000	0.0000	0.0000	0.0000
278	0.0000	0.0000	0.0000	0.0000
280	0.0000	0.0000	0.0000	0.0000
282	0.0000	0.0000	0.0000	0.0063
283	0.0000	0.0000	0.0000	0.0000
285	0.0353	0.0000	0.0000	0.0000
289	0.0000	0.0000	0.0000	0.0000
290	0.0000	0.0038	0.0000	0.0000
291	0.0000	0.0133	0.0255	0.0000
293	0.0000	0.0000	0.0063	0.0126
295	0.0000	0.0000	0.0000	0.0000
299	0.0000	0.0057	0.0095	0.0000
301	0.0000	0.0000	0.0000	0.0000
304	0.0000	0.0000	0.0000	0.0000
305	0.0054	0.0208	0.0542	0.0474
308	0.0000	0.0000	0.0000	0.0000
309	0.0000	0.0000	0.0000	0.0000
313	0.0114	0.0000	0.0000	0.0000
316	0.0152	0.0000	0.0000	0.0000
320	0.0000	0.0000	0.0000	0.0000
329	0.0000	0.0000	0.0000	0.0000
332	0.0000	0.0000	0.0000	0.0000
335	0.0000	0.0000	0.0000	0.0000
342	0.0000	0.0000	0.0000	0.0000
347	0.0000	0.0000	0.0000	0.0000
349	0.0000	0.0152	0.0000	0.0081
359	0.0000	0.0000	0.0000	0.0000
369	0.0000	0.0000	0.0000	0.0411
371	0.0000	0.0000	0.0128	0.0000
373	0.0000	0.0000	0.0000	0.0000
388	0.0000	0.0000	0.0000	0.0063
389	0.0000	0.0000	0.0063	0.0000
403	0.0000	0.0000	0.0000	0.0000
427	0.0000	0.0000	0.0000	0.0000
431	0.0000	0.0000	0.0000	0.0000
432	0.0000	0.0000	0.0063	0.0000

Appendix II

A. Taxa names and codes for macroinvertebrates

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

Tricoptera	200
Hydropsychidae	203
Diplectrona	207
Hydropsyche	204
Parapsyche	206
Cheumatopsyche	205
Potamyia	227
Macrostemum	208
Homoplectra	228
Phryganeidae	209
Phryganea	229
Agrypnia	230
Oligostomis	241
Hagenella	210
Rhyacophilidae	201
Rhyacophila	202
Philopotamidae	231
Dolophilodes	232
Chimarra	246
Wormaldia	771
Psychomidae	233
Psychomia	234
Polycentropididae	235
Neureclipsis	236
Polyantropis	242
Helicopsychidae	220
Helicopsyche	221
Molannidae	
Molanna	765
Uenoidae	237
Neophylax	238
Limnephilidae	239
Platycentropus	240
Pycnopsche	243
Chyranda	244
Psuedosteno-phylax	245
Apataniaidae	
Apatania	246
Goera	753
Glossosomatidae	216
Glossosoma	217
Leptoceridae	224
Oecetis	225
Ceralcula	226
Trianenodes	297
Lepidostomatidae	218

Ephemerellidae	501
Seratella	502
Drunnella	504
Ephmerella	503
Eurylophella	767
Oligoneuriidae	522
Isonychia	523
Polymitarcyidae	524
Ephoron	525
Ephemeridae	626
Ephemera	527
Litobrancha	528
Hexagenia	521
Caenidae	515
Caenis 516	
Leptophlediidae	520
Habrophleboides	521
Leptophlebia	754
Siphlonuridae	
Ameletus	511
Plecoptera	600
Chloroperlidae	614
Utaperla	618
Alloperla	615
Sweltsia	630
Peltoperlidae	607
Peltoperla	608
Perlidae 626	
Phasganophora	629
Perlesta	626
Pargenetina	632
Acroneuria	757
Capnidae	
Allocapnia	603
Paracapnia	631
Perlodidae	622
Clioperla	625
Remus	610
Leuctridae	620
Leuctra or Zealeutra	621
Isoperla	602
Taeniopterygidae	623
Taeniopteryx	624
Omeopteryx	613
Nemouridae	604
Amphinemura	605

CHIRONOMIDAE GENERA:

Taxon	Code #
Diamesinae	450
Diamesa	451
Pagastia	491
Prodiamesina	452
Prodiamesa	453
Tanypodinae	458
Conchapelopia	459
Ablabesmyia	460
Procladius	470
Hudsonimyia	461
Brundiniella	462
Clinotanypus	463
Rheopelopia	464
Larsia	465
Natarsia	466
Alotanypus	467
Meropelopia	468
Macropelopia	469
Zavrelimyia	492
Telopelopia	493
Pentaneura	495
Kenopelopia	499
Nilothauma	751
Chironominae	475
Strictochironomus	476
Cryptochironomus	477
Microspectra	480
Endochironomus	481
Polypedilium	482
Tribelos 483	
Rheotanytarsus	484
Corynoneura	489
Tanytarsus	485
Paratanytarsus	753
Mircotendipes	488
Chironomus	487
Polypedilium fallax grp	486
Dicrotendipes	494
Omisis 750	
Orthocladinae	420
Orthocladius (euorthocladius)	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
Data: SLIPPERY ROCK CREEK SURBER FALL 1999-FALL 2001

Table I. Data and Summary Statistics

Original Sample Units

Label	99FL44	99FL46	99FL61	99FL65	99FLWC	00SP44	00SP46	00SP61	00SP65	00SPWC
Totals	100.00	100.00	98.50	99.90	100.50	99.90	99.90	99.80	100.00	100.00
Species ID										
102	0.0000	0.0000	0.0000	0.0000	0.0318	0.0000	0.0000	0.0000	0.0000	0.0590
103	0.0000	0.0000	0.0000	0.0000	0.0000	0.3333	0.0000	0.2124	0.0000	0.0000
104	0.0000	0.0000	0.0000	0.0000	0.0000	0.3333	0.0000	0.0000	0.0000	0.0000
105	0.0000	0.0000	0.1005	0.0000	0.0000	0.0000	0.0000	0.0601	0.0000	0.0000
106	0.0000	0.0000	0.0000	0.1111	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
109	0.0000	0.2000	0.0000	0.1111	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
110	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0912	0.0000	0.0000
113	0.1670	0.0000	0.0558	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
115	0.0000	0.0000	0.0112	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
117	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
122	0.0000	0.0000	0.0112	0.0000	0.0149	0.0000	0.0000	0.0000	0.0000	0.0080
125	0.1660	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0140
202	0.0000	0.0000	0.0000	0.0000	0.0060	0.0000	0.0000	0.0611	0.0000	0.0000
203	0.0000	0.0000	0.0112	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
204	0.0000	0.0000	0.0112	0.0000	0.0318	0.0000	0.0000	0.0301	0.0000	0.0000
205	0.0000	0.0000	0.0000	0.3333	0.0418	0.0000	0.0000	0.0000	0.0000	0.0220
206	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0150
232	0.0000	0.0000	0.0223	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
243	0.0000	0.0000	0.0000	0.1111	0.0000	0.0000	0.0000	0.0301	0.0000	0.0080
300	0.0000	0.0000	0.0000	0.0000	0.0060	0.0000	0.0000	0.0000	0.0000	0.0000
301	0.0000	0.0000	0.0670	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
302	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0301	0.0000	0.0000
303	0.0000	0.0000	0.1107	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
306	0.0000	0.0000	0.0000	0.0000	0.0109	0.0000	0.0000	0.0000	0.0000	0.0000
309	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0080
310	0.0000	0.0000	0.1107	0.0000	0.3950	0.0000	0.0000	0.1824	1.0000	0.0450
402	0.0000	0.0000	0.0223	0.0000	0.0109	0.0000	0.0000	0.0301	0.0000	0.0080
405	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0080
407	0.0000	0.0000	0.0000	0.2222	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
422	0.0000	0.0000	0.0000	0.0000	0.0478	0.0000	0.0000	0.0000	0.0000	0.3130
423	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0150
432	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0301	0.0000	0.0000
433	0.1670	0.0000	0.0558	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1640
436	0.0000	0.0000	0.0000	0.0000	0.0060	0.0000	0.0000	0.0000	0.0000	0.0000
465	0.0000	0.0000	0.0782	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table I. Data and Summary Statistics

Original Sample Units

Label	00FL44	00FL61	00FL65	00FLWC	01SP44	01SP61	01SPWC	01FL44	01FL60	01FL61
Totals	99.90	100.10	100.10	100.30	99.80	99.80	100.70	99.70	100.20	99.70
Species ID										
102	0.0000	0.0000	0.0000	0.0419	0.0000	0.0000	0.0745	0.0451	0.0000	0.0000
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	0.0000	0.0000	0.0000	0.0000
110	0.0000	0.0000	0.0649	0.0050	0.0000	0.0000	0.0000	0.0000	0.0200	0.0000
113	0.1111	0.0100	0.0000	0.0000	0.0000	0.0000	0.0000	0.1364	0.0000	0.0341
115	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0451	0.0000	0.0000
117	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0129	0.0000	0.0000	0.0000
121	0.0000	0.0000	0.0000	0.0000	0.2144	0.0000	0.0000	0.0000	0.0000	0.0000
122	0.0000	0.0000	0.0649	0.0000	0.0000	0.0000	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	0.0110
204	0.1111	0.0000	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	0.0000	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	0.0000	0.0200	0.0000
301	0.1111	0.0000	0.0000	0.0030	0.0000	0.0000	0.0000	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	0.0000
307	0.0000	0.0050	0.0000	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	0.0000	0.0000	0.0000	0.0000	0.0000
430	0.0000	0.0050	0.0000	0.0000	0.0000	0.0000	0.0000	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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0913
433	0.3333	0.0000	0.0000	0.0419	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
435	0.0000	0.0000	0.0000	0.0419	0.0000	0.0000	0.0129	0.0000	0.0000	0.0000
461	0.1111	0.0050	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
465	0.0000	0.0050	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0231
480	0.0000	0.0050	0.0000	0.0000	0.0000	0.0000	0.0000	0.0451	0.0000	0.0000

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

Hill's Numbers

N(0)	10.0000	22.0000
N(1)	5.9343	6.2684
N(2)	3.7308	3.7430

Hill's Ratios

N(1)/N(0)	0.5934	0.2849
N(2)/N(1)	0.6287	0.5971
N(2)-1/N(1)-1	0.5534	0.5206

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

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

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

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

Abstract

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

1. Introduction

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

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

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

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Table 1
General chemical and biological parameters at the two stream sites used for experiments in the study, Slippery Rock Creek (at AMD impacted Station 65) and Wolf Creek (unimpacted reference stream)[a]

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 $CaCO_3\ l^{-1}$)	11.7 (4.1–40.0)	76.2 (24.9–149.9)
Acidity (mg $CaCO_3\ l^{-1}$)	8.3 (3.4–13.6)	2.5 (0–8.3)
Sulfate (mg l^{-1})	255 (245-260)	70 (60-79)
Soluble Fe (mg l^{-1})	0.40 (0.20–1.88)[b]	0.04 (bd[c]–0.19)
Soluble Mn (mg l^{-1})	4.10 (bd–9.50)[c]	0.08 (bd–0.1)
Soluble Al (mg l^{-1})	0.10 (bd–0.55)[c]	0.14 (bd–0.40)[c]
Soluble Zn (mg l^{-1})	0.07 (bd–0.12)[c]	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 (0–54)	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)
Epilithic periphyton species richness	21 (14–31)	23 (18–37)

[a] 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.

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

3. Materials and methods

3.1. Substratum experiment

To examine the effects of AMD precipitate on epilithic invertebrates and periphyton, 30.5×30.5×4.0 cm wooden frames with 1.0 cm^2 open mesh, plastic bottoms were filled with cobble-sized substrata obtained from a quarry. To obtain substratum treatments with an AMD coating, frames filled with either sandstone or limestone cobble were placed in a highly impacted, untreated 2nd order AMD stream in the headwaters of Slippery Rock Creek for 3 weeks to accumulate a precipitate coating approximately 0.5 mm thick (estimated visually by scraping the substratum). This stream contains few to no macroinvertebrates and a visual inspection of the cobbles in the trays indicated no invertebrates were present after the 3-week exposure. These trays were then transferred in water-filled containers to a circumneutral stream with good water quality, Wolf Creek, on 13 October 1998. On the same date, substratum trays containing either clean, washed limestone or clean, washed sandstone treatments were also placed in Wolf Creek. Five replicates of the four substratum treatments, clean (control) sandstone, clean (control) limestone, AMD coated sandstone and AMD coated limestone, were located randomly in a long riffle of the stream for a 4-week exposure. Metals were sampled from the substratum in the trays before and after being placed in Wolf Creek. Substratum in the trays were sampled for macroinvertebrates and periphyton at the end of the 4-week exposure.

To examine changes in metal concentrations on the substrata during the 4-week exposure, randomly selected cobbles from trays of each treatment ($n=5$) were analyzed for metals before and after being placed into Wolf Creek. The entire surface of each rock was scrubbed with a hard bristle, plastic-brush using a 2% HNO_3 solution. Material scrubbed and rinsed from the cobble was digested for metal analyses using nitric acid (digestion procedure 303E, APHA, 1998). Concentrations of Al, Fe, Mn, and Zn were determined using a Perkin Elmer Plasma 400, inductively coupled plasma spectrophotometer (ICP; preliminary studies have shown these to be the most abundant metals). Accuracy and precision of metal analyses were determined by running duplicates, blanks, standards and spiked samples at a frequency of approximately 1 per 10 normal samples. Samples outside of limits of acceptability (10%) were rerun (APHA, 1998).

Invertebrates from each tray were sampled by placing a 500-μm mesh net directly downstream of the tray and rubbing invertebrates off each cobble by hand into the net. Invertebrate samples were preserved in 70% ethanol and individuals identified to genus using primarily Peckarsky et al. (1984). Prior to invertebrate sampling, one randomly selected cobble was taken from three of the five trays for each treatment to sample periphyton significant interaction between substrata treatment and change in concentrations during the 4-week exposure in Wolf Creek (Fig. 1A). Iron concentration did not change significantly on either the sandstone or limestone control substrata but significantly decreased on both AMD substrata. Aluminum concentrations were significantly different among substrata treatments and were higher on AMD sandstone than control sandstone substrata. There was a significant interaction between substrata treatment and the changes in Al concentrations, with all treatments losing aluminum during the exposure except sandstone control (Fig. 1B). Concentrations of manganese and zinc on the rocks were quite a bit lower than for Fe and Al, with all values less than 0.01 mg cm^{-2}. Changes in Mn concentrations on the rocks were also significantly affected by the substrata treatment. Unlike the other metals, control substrata treatments significantly gained Mn during the experiment, but there was not a significant increase on the AMD treatments 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 macroinvertebrate densities were not significantly different among substrata treatments, although they were slightly higher on control treatments (Fig. 2). Shannon diversity values for macroinvertebrates varied from 1.0 to 1.4 and were not significantly different among treatments (Table 2). Taxonomic composition of the macroinvertebrates on the four substrata treatments was similar, with the stonefly, *Taeniopteryx* sp., and the mayfly, *Isonychia* sp., dominating the assemblages. Each of the five most abundant macroinvertebrate taxa did not differ significantly in their relative abundance

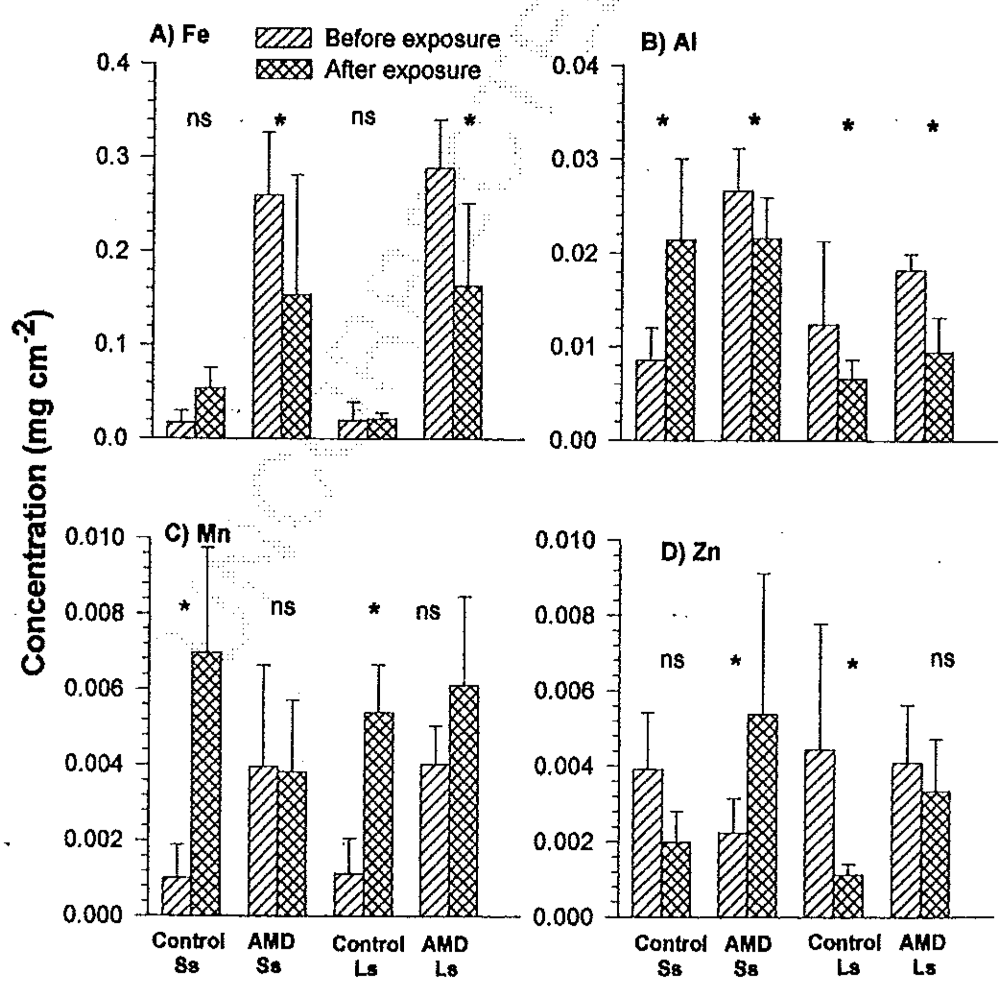

Fig. 1. Mean concentrations of Fe, Mn, Al and Zn on four substrata treatments before and after exposure in an unimpacted reference stream, Wolf Creek. Asterisks indicate a significant change ($P<0.05$) in concentration during the exposure within each treatment. Error bars are 1 SE, $n=5$. Ss, sandstone,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

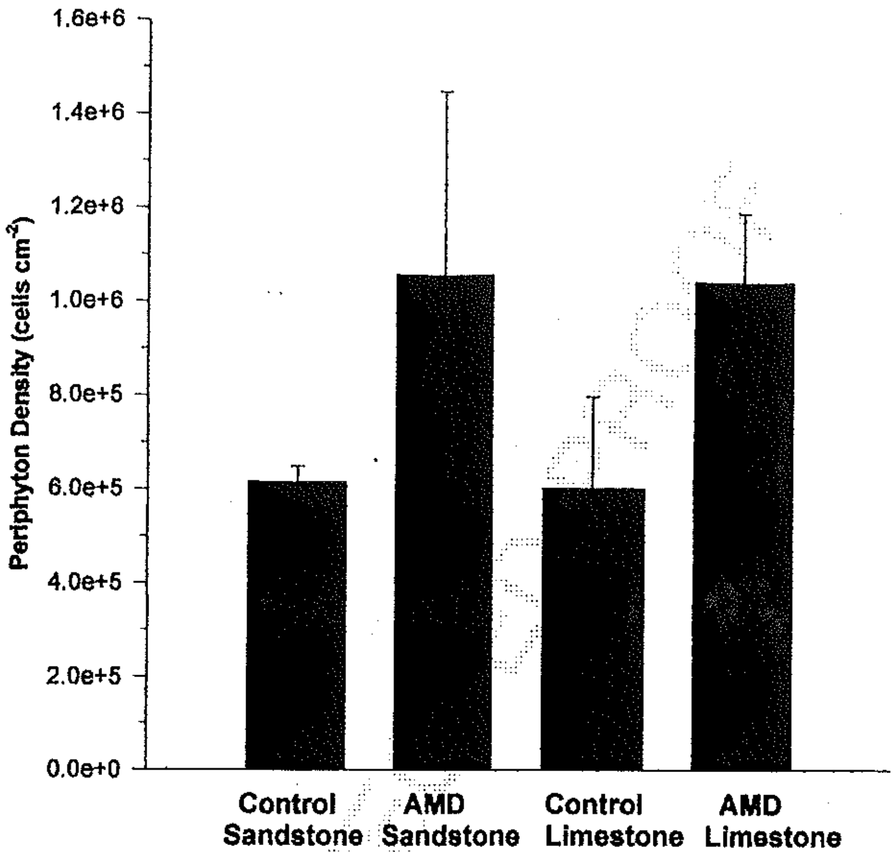

Fig. 3. Mean density of periphyton on four substrata treatments after a 4-week exposure in an unimpacted reference stream, Wolf Creek. Error bars are 1 SE, $n=3$.

Table 3
Taxonomic composition, as percent, for the most abundant periphyton taxa and Shannon Diversity on four substrata treatments[a]

	Control sandstone	AMD sandstone	Control limestone	AMD limestone
Genus				
Nitzschia dissipata	25.9 (1.2)	28.9 (2.6)	30.2 (1.4)	34.8 (2.3)
Navicula gregaria	19.6 (1.2)	22.0 (2.9)	19.6 (2.9)	21.1 (3.4)
Navicula cryptocephala	9.6 (1.2)	9.4 (1.2)	9.9 (1.1)	5.9 (1.2)
Navicula minuscula	8.7 (1.9)	7.9 (2.6)	6.1 (1.1)	9.5 (1.4)
Navicula tripunctata	5.8 (1.3)	4.6 (0.8)	6.8 (1.3)	4.6 (0.7)
Navicula cryptotenella	2.1 (0.2)	2.9 (0.7)	2.5 (0.4)	2.5 (0.5)
Diversity				
Shannon Diversity	3.2 (0.2)	3.4 (0.2)	3.2 (0.1)	3.1 (0.3)

[a] Values are means (1 SE), $n=3$.

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

4.2. Aqueous exposure of caddisflies

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).

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

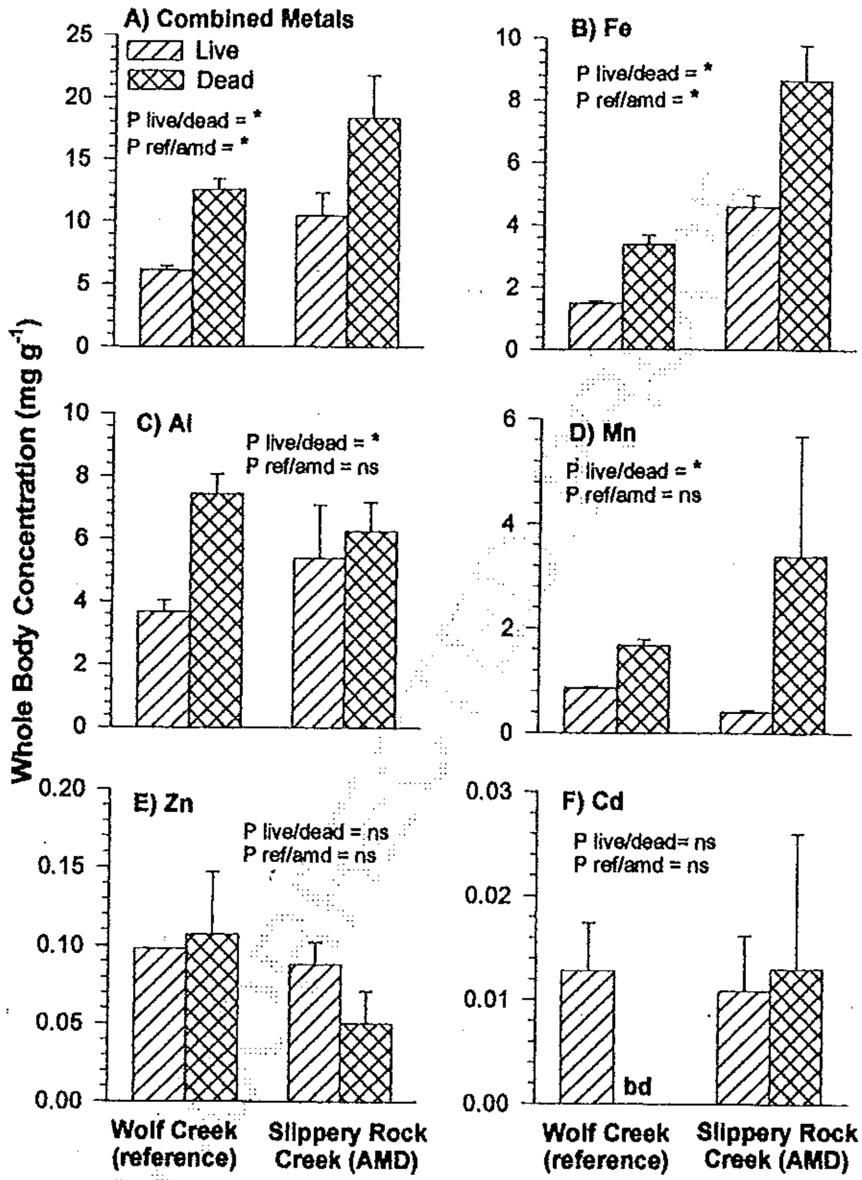

Fig. 4. Mean whole-body concentrations of Fe, Al, Mn, Zn, Cd and combined metals for live and dead hydropsychid caddisflies after a 5-day exposure in Slippery Rock Creek (at AMD impacted Station 65) and Wolf Creek (unimpacted reference stream). Error bars are 1 SE, $n=7$. bd, below detection limits. 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. Concentrations of Zn and Mn on the substrata were 1–2 orders of magnitude lower than Fe and Al. Under oxidizing conditions, precipitation of Mn is much greater at pH > 6 (Hedin et al., 1994) and thus more likely in Wolf Creek than the AMD site, however aqueous concentrations in Wolf Creek were very low. It is likely changes in the concentration of Zn and Mn after exposure in Wolf Creek may have been relatively more affected by formation of a biofilm containing these elements than by changes in mineral solubility or adsorption.

After the 4-week exposure in Wolf Creek, there were no significant differences between AMD coated and control substrata in abundance or taxonomic composition of invertebrates or periphyton. Several aquatic invertebrates have been shown to be tolerant of high to moderate levels of dissolved Fe (Rasmusssen and Lindegaard, 1988; Gerhart, 1992; Rousch et al., 1997). However, studies of mine drainage in which stream pH values are circumneutral and dissolved metals low, have suggested that loose, unattached precipitates of ferric iron hydroxides can have devastating affects on invertebrate when uptake exceeds the organisms ability to regulate the metal or bind it in a nonlethal form (Hare, 1992; Gerhart, 1993). While the pH of Slippery Rock Creek during the exposure was over 6.0, it was lower than the pH of Wolf Creek and it was likely to have a greater concentrations of more toxic, free-ion forms of the metals (Table 1). Caged caddisflies in the AMD impacted stream had significantly higher concentrations of most of the measured metals, with concentrations of Fe and Al being the highest. Most aquatic animals regulate Fe well and LC50 values for dissolved Fe are relatively high (3–300 mg l^{-1}; Gerhart, 1993, 1994). Precipitation of Fe hydroxides can decrease survival because of disruption of intestine membranes, clogging of the digestive tract, and coating of gill surfaces (Gerhart, 1992, 1993). Although no visible orange precipitate was seen on the caddisflies placed in the AMD site, precipitate formed on the cages in that stream indicating that some precipitation of Fe on the organisms was more likely than in Wolf Creek. Toxicity of Al on aquatic insects appears to result mainly from affects on gills and respiration (Rosenberg and Resh, 1993). While dissolved ionic Al can disrupt ion transport across gill membranes, respiration can be also affected in part by precipitation of Al hydroxide on gill surfaces. Krantzberg and Stokes (1988) found maximum Al body burdens of chironomids were greatest between pH 5.1 and 5.6, a level close to the pH at our AMD site.

Comparison of whole-body concentrations in live vs. dead caddisflies implies that although active ingestion of metals can lead to toxic internal affects, passive uptake of metals on external body surfaces also can be an important uptake mechanism in hydropsychid caddisflies, which may lead to chronic lethal affects associated with gills or sensitive surfaces. It was surprising that dead caddisflies had higher total body concentrations than live for all metals, as most studies find little difference in metal uptake between live and dead aquatic insects (Timmermans et al., 1992). Iron in the gut contents of hydropsychid caddisflies make up 34–60% of the Fe in the whole body (Smock, 1983; Cain et al., 1995), and we assumed active uptake of filtered seston would increase metal concentrations in live organisms in the AMD stream. Dead caddisflies were depurate and their mass was about half that of live, thus it appears that metals associated with passive surface sorption increased the whole-body concentrations in dead organisms. Other factors that could increase the concentration of metals in dead vs. live caddisflies are the release metals sequestered in granules near the body surface after death (Krantzberg and Stokes, 1988), the release of proteins in killed organisms that then adsorb metals from solution (Timmermans et al., 1992), the lack of metal regulation/excretion in dead organisms, and the possibility that metals precipitated on the retreats and nets of live hydropsychid caddisflies, rather than on the body surface (Letterman and Mitsch, 1978; Brown, 1977).

6. Conclusions

Understanding the relative roles of substratum and aqueous chemical affects of AMD on benthic organisms is critical to successful remediation of impacted streams. The building of passive systems to treat coal mine discharges entering streams has increased substantially in the past 5 years (Milavec, 2000; Rossman et al., 1997), but there has been little examination of the relative roles of the benthic vs. aqueous environment on the recovery of stream benthos. Results from this study indicate that aqueous AMD chemical environment in Slippery Rock Creek had a greater affect on organisms than the chemical precipitate on substrata. Hard substrata coated with AMD precipitate had a significant decrease in the most abundant metals, Fe and Al, and a benthic flora and fauna similar to control substrata when placed into an unimpacted aqueous environment, whereas caddisflies exposed to a moderately impacted aqueous AMD environment had significantly higher mortality and metal concentrations in their bodies. While treatment of several large AMD inputs into Slippery Rock Creek have improved the overall aqueous environment, water chemistry appears to continue to limit the recovery of benthic organisms. Increased AMD discharge during storm events can overwhelm or bypass treatment systems, and the temporary deterioration in stream water quality can increase the negative impact on benthic organisms (Verb and Vis, 2000; DeNicola and Stapleton, 1999). Moreover, decades of accumulated AMD precipitate deposited on the substratum may now be out of equilibrium with the treated aqueous environment, and thus be a source of aqueous metals. Our study suggests improvement in water quality resulting from passive treatment systems should aid in the recovery of the chemical and biological environment of the substrata in AMD affected streams. While AMD affected substrata recovered quickly in our transplant experiment, the cobble was coated with a thin, recently deposited precipitate, which is most representative of riffle areas where flocculent precipitates do not accumulate. Sections of other streams and Slippery Rock Creek that have accumulated layers of encrusted and flocculent AMD precipitate may take substantially longer to recover given improved water quality.

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