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Mountaintop Mining/Valley Fills in Appalachia
Draft Programmatic
Environmental Impact Statement

APPENDIX D

Aquatic Technical Studies

APPENDIX D

Aquatic Study Category, **Appendix D**

Study Topic	**File Date**
West Virginia Macroinvertebrate Study	11/2000
West Virginia Stream Chemistry Study	4/8/2002
Kentucky Macroinvertebrate Study	10/2001
Survey of Eight Aquatic Insect Orders Associated with Small Headwater Streams Subject to Valley Fills from Mountaintop Mining	11/02/2002
Fisheries Study	10/12/2002
Aquatic Impacts Statistical Report	4/15/2003
Workshop on the Value of Headwater Streams	4/2000
Flow Origin, Drainage Area, and Hydrologic Characteristics for Headwater Streams in the Mountaintop Coal-Mining Region of Southern West Virginia, 2000-01	3/2003
Reconnaissance of Stream Geomorphology, Low Streamflow, and Stream Temperature in the Mountaintop Coal-Mining Region, Southern West Virginia, 1999-2000	2001
Wetlands Study	11/8/2001
Aquatic Ecosystem Enhancement	1/12/2000

Macroinvertebrate and water quality studies were performed in several watersheds located in both West Virginia and Kentucky to assess the impact of MTM/VF on aquatic resources. Hydrologic and biological studies were also conducted in several West Virginia streams in an effort to demarcate ephemeral, intermittent, and perennial stream zones.

West Virginia Macroinvertebrate Study by EPA Region III, Wheeling Field Office

The study had the following objectives:

> *Characterize and compare conditions in three categories of streams: 1) streams that are not mined; 2) streams in mined areas with valley fills; and 3) streams in mined areas without valley fills. Characterize conditions and describe any cumulative impacts that can be detected in streams downstream of multiple fills. Characterize conditions in sediment control structures (ditches) on MTR/VF operations.*

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The data indicated that streams with both valley fills and residences in their watersheds appeared to be more impaired than streams with only valley fills (no residences) in their watersheds. Biological conditions at the unmined sites were compared to a broad state-wide wadeable streams reference condition developed by the West Virginia Department of Environmental Protection (WVDEP). This reference condition was based on a data set of 1268 benthic samples collected from 1996 to 1998. This reference condition defines condition categories of very good, good, fair, poor and very poor based on Stream Condition Index (SCI) scores. Scores in the fair, poor and very poor range are impaired relative to the reference condition. Biological conditions in the filled sites generally represented a gradient of conditions from poor to very good. Biological conditions in streams with filled/residential sites (filled sites that also have residences in their watersheds) represented a gradient of conditions from poor to fair.

Biological conditions in the filled and filled/residential classes were recognizably different from conditions in the unmined class and were impaired relative to conditions in the unmined class, based on the WV SCI scores. The filled/residential class was the most impaired class. The causes of impairment in this class could include several stressors (e.g. the valley fills, the residences, roads). It is impossible to apportion the impairment in this class to specific causes with the available data.

Cumulative impacts downstream of multiple fills were not successfully determined although biological conditions were impaired at the downstream sites compared to the upstream sites. The observed impairment could be caused by several stressors, including mining and residential land use which could not be separated.

Only one sediment control structure was selected as candidate monitoring site since most sites were not reconstructed as streams. Therefore, the objective to characterize these structures was not met.

Questions remain concerning the extent to which downstream impacts identified in this study may be influenced by the size, number, and age of fills and the impact that these changes in the macroinvertebrate community may have on the downstream terrestrial and aquatic communities. A limiting factor that should be considered is that most sites evaluated as mined were not necessarily reflective of current mining methods and programmatic controls. These questions will require additional investigation.

Kentucky Macroinvertebrate Study by EPA Region IV

This study was designed with the following objective:

> *Determine if streams in mined watersheds were being impacted by mountaintop mining and valley fill (MTM/VF).*

Measures of *in situ* water quality, habitat quality and macroinvertebrate community structure were found to be related to mining activities. In particular, conductivity was considerably higher at all mined sites than it was at reference sites. Conductivity produced the strongest correlation to indicators of macroinvertebrate community health suggesting this as either a route by which impairment occurred in mined areas, or that conductivity is a surrogate for other factors that were not measured. Severe impact to the mayfly (Ephemeroptera) fauna was exhibited at all mined sites. Habitat scores, generally lower at sampling locations downstream of mined areas than at reference sites, were correlated to several measures of diversity and dominance of key groups of macroinvertebrates. Impacts of MTM/VF activities in eastern Kentucky were evident based on stream biological and habitat indicators. Mine sites generally had higher conductivity, greater sediment deposition, smaller substrate particle sizes, and a decrease in pollution sensitive macroinvertebrates with an associated decrease in taxa diversity compared to reference sites.

However, just as in the West Virginia Study, no attempt was made to correlate changes in water quality or quantity and subsequent changes in the macroinvertebrate community to the numbers of valley fills present, the age of the fills, size of the fills or the influences that downstream distance may have on the sampling results. Also, sampling periods for the Kentucky study were limited. As such, additional studies are needed to more fully evaluate the impacts of valley fills on the aquatic and indirectly on the terrestrial community.

Survey of Eight Aquatic Insect Orders Associated with Small Headwater Streams Subject to Valley Fills from Mountaintop Mining by Stout, Wallace, et. al.

The objective of this study was:

Assess the potential limits of viable aquatic communities based on biological criteria.

Six headwater sites in West Virginia and two sites in Kentucky were selected for study. Six of the eight sites had three or more headwater streams planned for valley fills. A total of 34 streams and spring seeps were surveyed in West Virginia and Kentucky, which included 175 sampling locations or stations. Each headwater stream or spring seep was located in the field, where the contiguous surface flow began. Other sampling locations were located 50, 150, 350, and 550 meters downstream of the point of contiguous flow. Aquatic stages were taken with a D-frame net and/or hand picked with forceps from rocks, twigs and branches, leaf-packs and other substrate. Organisms (macroinvertebrates) were counted and identified to the family or genus level and the data recorded on field sheets.

Most sites would not be considered streams based on existing USGS 1:24000 topographic maps. However, a number of taxa that are found in these extreme headwaters have multi-year life cycles suggesting that sufficient water is present for long-lived taxa to complete their juvenile development prior to reaching the aerial adult stage. The predominance of shredder taxa in the headwaters suggests that the community structure in the extreme headwaters resemble those hypothesized by the river continuum concept for first order streams (Vannote et al. 1980). These streams all drained forested regions and leaf material from the surrounding forest was by far the most evident energy source.

Invertebrates inhabiting temporary streams can have high diversity and faunal similarity with permanent streams, therefore they should be considered in conservation plans designed to protect species and their habitats.

New questions remaining: Much more work is needed on organic matter dynamics, e.g., input and output budgets, etc. in small headwater streams of the central Appalachians. The trend of increasing fine organic particle collectors downstream and higher shredder populations upstream suggests a system that is dependent on linkages upstream resources and surrounding forest.

West Virginia Stream Chemistry Study by EPA Region III, Wheeling Field Office

The objectives of this study were the following:

> *Characterize and compare conditions in three categories of streams: 1) streams that are not mined;2) streams in mined areas with valley fills; and 3) streams in mined areas without valley fills. Characterize conditions and describe any cumulative impacts that can be detected in streams downstream of multiple fills.*

Thirty seven (37) sites were divided into three watershed categories: unmined, mined, and filled. The initial evaluation seeks to identify parameters likely to be impacted by MTM/VF mining**.** The average water quality at all Filled sites is compared to the water quality at all Unmined sites sampled during this study. A second approach in this evaluation is to identify the samples and sites which exceeded West Virginia's stream water quality criteria. Sites which have multiple violations are described and characterized.

The data indicate that MTM/VF mining activities increase concentrations of the several parameters in streams. Sites in the Filled category had increased concentrations of the following parameters: sulfate, total calcium, total magnesium, hardness, total dissolved solids, total manganese, dissolved manganese, specific conductance, total selenium, alkalinity, total potassium, acidity, and nitrate/nitrite. There were increased levels of sodium at sites in the category Filled/Residences which may be caused by road salt and/or sodium hydroxide treatment of mine discharges.

The data were inconclusive for several other parameters which were detected in only a few samples or at very low concentrations. Those parameters: total phosphorous, total copper, total lead, total nickel, total barium, total zinc, total organic carbon, dissolved organic carbon, and total suspended solids. Other parameters were detected but there was no clear indication of stream impacts resulting from MTM/VF mining operations. Those parameters are: chloride, total aluminum, dissolved aluminum, total iron, dissolved iron, temperature, dissolved oxygen, and pH. Data indicated that only three samples for total aluminum exceeded the stream criterion and all were collected August 9, 2000 at sites with fills upstream. Dissolved aluminum was detected in only five samples and all were near the detection limit of 100 ug/L. There were no samples for total iron exceeding the stream criterion but several samples in the category Filled approached the limit in the fall of 2000. Dissolved iron was detected at a few sites in the category Filled at levels slightly higher than other sites. MTM/VF mining operations can increase iron concentrations in streams but there is no clear evidence that this occurred during the study. Temperature, pH, conductivity, and dissolved oxygen were measured in the field. The only field parameter clearly impacted by MTM/VF mining was conductivity which was noticeably increased at sites in the Filled category.

The initial sampling was discarded for quality control reasons. Only the data from the second half of the study was used to evaluate compliance with stream limits due to problems with contamination in blanks and excessive holding times which occurred during the first part of this study. All sampling data used was fully compliant with QA/QC procedures. The latter data indicate that MTM/VF mining is associated with violations of the current stream water quality criteria for total selenium. Selenium violations were detected in each of the five study watersheds and all were at sites in the Filled category, downstream of MTM/VF operations. No other site categories had violations of the selenium limit. The data do not support a conclusion regarding stream water quality violations for aluminum, dissolved oxygen, iron or pH which can be impacted by MTM/VF mining activities.

A number of questions or issues remain to be resolved. Several stream quality parameters exhibited anomalous concentrations. The potential effects of existing mineralogical or geological controls on water quality composition is uncertain. The extent to which downstream impacts may be influenced by the size, number and age of fills and the extent to which downstream distance may influence study findings was not determined. Loss of the initial sampling data made analysis of seasonal variation of water quality difficult to evaluate. Identification of the specific sources of pollutants were not incorporated into the study design. A limiting factor that should also be considered is that most sites evaluated as mined were not necessarily reflective of current mining methods and programmatic controls. As such, further data analysis concerning these issues is being considered.

Fisheries Study by Dr. Jay Stauffer, Pennsylvania State University

This study was designed to answer the following questions:

> *Characterize the fish communities that exist in the primary region of mountain top removal/valley fill coal mining in West Virginia and Kentucky. Determine if any unique fish populations exist in this area. Evaluate the effects of these mining operations on fish populations residing in downstream areas.*

Fish assemblages were sampled in 58 sites in West Virginia located on 1st through 5th order streams, and in 15 sites in Kentucky located on 2nd, 3rd, and 4th order streams. Sites were selected in consultation with U.S. EPA personnel to characterize the fish communities in the primary region of mountaintop removal/valley fill coal mining.

Due to the confounding effects of drought, small stream size (low stream order), and human impact on reference sites in West Virginia, a comparison of reference (unmined) sites to filled sites could

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not be made directly during the 1999/2000 sampling season. Comparisons of unmined sites and filled sites in Kentucky and in 2nd order streams in the New River Drainage indicate that mountaintop mining/valley fill coal mining has impacted the streams. In general, the number of total species and benthic species were substantially lower in filled sites that in mined sites in both Kentucky and 2nd order streams in the New River Drainage.

The uniqueness of this area is emphasized by the collection of species of *Cottus* with features that are rare in the population. The continued disruption of streams may eliminate the genetic diversity that may lead to speciation. Further observations and studies are suggested.

Aquatic Impacts Statistical Report by EPA Cincinnati Laboratory

The questions this report was designed to answer are as follows:

> *Is the biological condition of streams degraded by mining compared to unmined areas? Are there additive (cumulative) impacts downstream of mining compared to unmined areas?*

Databases were assembled from mining companies MTM EIS technical studies for chemistry, fish, and macroinvertebrates. Statistical analyses were applied to the data using accepted indices and comparisons to determine correlation of parameters in unmined, filled, filled/residential and mined sites. The analysis indicates that biological integrity is impaired by mining. Unmined sites have a higher biotic integrity. Unmined sites have more taxa and more sensitive taxa. The strongest association with water chemistry suggested that zinc, sodium, and sulfate concentrations were negatively correlated with fish and macroinvertebrate impairments. Selenium and zinc were negatively correlated with the West Virginia Stream Condition Index (WVSCI). The potential drivers of the impaired condition are mining practices and material handling practices and the geological factors associated with specific coal seams and overburden.

The limitations of the study include lack of data on the age of fills, size of fills, characterization of materials handling practices, the influence of specific geological factors such as coal seams and overburden, and the extent to which distance between fills and sample sites affects study findings. There was little QA/QC data provided for the mining company data. Questions still remain on the downstream impacts relative to the size, number and age of fills and the influence of stream flow variations. Further data analysis concerning these issues is being considered. The report for this study was completed in April 2003 and did not undergo EIS Steering Committee review. Continued sampling at Unmined and Filled sites would improve the understanding of whether MTM/VF activities are associated with seasonal variation in benthic macroinvertebrate metrics and base-flow hydrology.

Workshop on the Value of Headwater Streams by U.S. Fish and Wildlife Service

The FWS Pennsylvania Office hosted this workshop April 13, 1999, to review research findings and provide an opportunity for discussion among research scientists and technical staff in the agencies responsible for the EIS. The workshop was proposed to gather information to answer the following questions:

> *At what point in the upper reaches of a stream do regulators stop regulating? How far upstream should we regulate to ensure that downstream functions and quality are maintained? Are stream classifications such as perennial, intermittent, or ephemeral ecologically useful or even relevant in this context? In evaluating the cumulative impacts of more than one valley fill, what size watershed do we evaluate? How many streams can be eliminated by valley filling in a given watershed before the downstream aquatic ecosystem is unacceptably impaired? If we assume that the amount of overburden material that needs to be disposed of is a constant, is one valley fill or a few very large valley fills better for the environment that more numerous small valley fills at the upper reaches of more valleys?*

The proceedings provide information on the current knowledge about headwater streams, which are little understood outside of scientific circles. Meeting participants discussed the fact that historically, small streams may have been under-protected by regulatory agencies because of uncertainty about their values. An industry representative discussed potential opportunities to create wetlands and stream channels as part of reclamation. The stream experts raised concern that many headwater streams were being eliminated by valley filling with no requirement for pre-impact biological inventories, and that many species may be unknowingly lost from the study area's unique ecosystem. They also stressed the importance of small, forested headwater streams and their associated biological communities in providing organic production that feeds downstream aquatic ecosystems. Opinions were expressed that although the current knowledge is far enough advanced to be able to say that headwater streams are too important to be eliminated, the current information is not sufficient to be able to decide what portions of watersheds can be filled before aquatic ecosystems are unacceptably impacted.

As this was an educational symposium and not a specific investigation, there are no study limitations to discuss.

Reconnaissance of Stream Geomorphology, Low Streamflow, and Stream Temperature in the Mountaintop Coal-Mining Regions, Southern West Virginia, 1999-2000 by U.S. Geologic Survey

The objective of this study was to provide the following information:

> *Present comparisons of streambed materials, stream-channel characteristics, low streamflow, and stream temperature among sites with and without valley fills.*

The effects of MTM/VF created in southern West Virginia were investigated by comparing data collected at valley-fill, mined, and unmined sites. Bed material downstream of valley-fill sites had a greater number of particles less than 2 millimeters and a smaller median particle size than the mined sites. Bankfull cross-sections areas at a riffle section were approximately equal at valley-fill and unmined sites, but not enough time had passed and insufficient streamflows since the land was disturbed may have prevented the stream channel at valley-fill sites from reaching equilibrium. Daily streamflows from valley-fill sites generally were greater thatn daily streamflows from unmined sites during periods of low streamflow. Valley-fill sites have a greater percentage of base-flow and a lower percentage of flow from storm runoff than unmined sites. Water temperatures from a valley-fill site exhibited lower daily fluctuations and seasonal variations than water temperatures from an unmined site.

Continued investigation at Unmined and Filled sites would improve the understanding of how MTM/VF activities are associated with seasonal variation in stream geomorphology, stream temperature and base-flow hydrology.

Flow Origin, Drainage Area, and Hydrologic Characteristics for Headwater Streams in the Mountaintop Coal-Mining Region of Southern West Virginia, 2000-01 by U.S. Geologic Survey

The objective of this study was to provide the following information:

> *Determine the median drainage area upstream of ephemeral/ intermittent/perennial flow boundaries in the Mountaintop Coal Mining Region of Southern West Virginia.*

State and Federal rules define stream reaches based on a variety of physical or biological characteristics such as navigability, ordinary high water marks, flow conditions, biological activity, or some combination of these attributes.

A field investigation using a hydrologic protocol developed by the United States Geological Survey (USGS), West Virginia Water Resources Division District Office, was undertaken to illustrate the size of watersheds attributable to each type of stream segment within the study area using this type of approach. To establish the ephemeral/intermittent demarcation (E-point), the field investigation was undertaken during the Spring of 2000, when the ground water table was considered to be at its maximum. To establish the intermittent/perennial demarcation (P-point), the field investigation was undertaken during the Fall of 2000, when the ground water table was considered to be at its minimum. The locations were documented with GPS and mapping. The results are as follows. The drainage areas for the ephemeral/intermittent boundary (E-point) varied from 6 to 45acres, with a median of 14 acres. The drainage areas for the intermittent/perennial boundary (P-point) ranged from 10 acres up to 150 acres, with a median of 41 acres.

Wetlands Study by EPA Region III

The study was designed to answer the following questions:

> *To what degree are the drainage control measures being established on fills able to replace aquatic habitats that existed prior to construction of the fill, and can designs be modified to further enhance or accomplish this?*
>
> *Regarding the effectiveness of existing forms of mitigation associated with valley fills in replacing or providing substitute resources, can existing forms of mitigation be modified to further enhance or accomplish this?*

It has been reported that wetland communities are being established at reclaimed mine sites, often within sediment retaining structures, or in other ponded areas on the mined sites. The extent of these areas, or the functions they are providing, however, was uncertain. To gather information in this regard, a field team performed functional assessments (water quality, wildlife, and sediment trapping) of ten wetland sites suggested by coal companies. The Evaluation of Planned Wetlands (EPW) technique developed by Environmental Concern, Inc. was utilized to perform these field assessments. EPW is rapid-assessment procedure designed for use during the planned wetland process.

The functions being provided by the wetland systems studied were varied. Many of the wetland systems were providing excellent sediment stabilization functions, and a few were providing good water quality (defined as the capacity to retain and process dissolved or particulate materials to the benefit of downstream surface water quality) and wildlife functions. Sediment stabilization is not a difficult function to establish in a wetland system. Water quality functions such as nutrient retention are also possible to establish with modest planning. In many of these cases where this function was not being provided, we suspect that the wetland systems were largely unplanned, and that the low percent vegetative cover was a significant influence in the low score. Finally, wildlife functions are highly dependent on the vegetative communities present, the degree of interspersion, and other physical and biological features of the system. It is not surprising, therefore, to see that this function did not score highly in many of the linear systems studied. Those areas that scored highly for wildlife function tended to be older systems with more complex structures.

Advanced planning could improve the modest wetland functions evident at existing surface mining facilities.

Aquatic Ecosystem Enhancement by U.S. Department of Energy, National Energy Technology Laboratory

The Mountaintop Mining/Valley Fill Environmental Impact Statement (EIS) Steering Committee sponsored a symposium on January 12, 2000 as a forum to present current information regarding aquatic ecosystem enhancement opportunities at mountaintop mining sites. Ecological and stream restoration experts were assembled from a number of disciplines to focus on the subject of stream (or other aquatic area) re-creation on mined sites. The proceedings from this symposium can be viewed at the U.S. Department of Energy, National Energy Technology Laboratory web site http://www.netl.doe.gov.

As this was an educational symposium and not a specific investigation, there are no study limitations to discuss.

soyedi	Question ina	Site ID	Distance(m)	WSHED_ACRE	ELEV_FT	ASPECT	total#collected	EPT taxa	Richness	#multi-year	%shredders	%grazers	%collectors	%pr rs
		c1.1	0	145.464	1516.414	SW	0	0	0	0	0	0	0	
		c1.2	50	164.763	1509.139	W	4	2	2	0	0.25	0	0.75	
		c1.3	150	170.828	1494.390	N	4	2	2	0	0.25	0	0.75	
		c1.4	650	202.192	1467.595	N	37	4	7	0	0.0810811	0	0.8648649	0.0
		c3.1	0	29.560	1757.348	SW	47	8	10	0	0.4468085	0.0851064	0.3829787	0.0
		c3.2	50	31.042	1748.775	S	26	8	11	0	0.3846154	0	0.5769231	0.0
		c3.3	150	49.884	1731.036	SE	35	8	10	0	0.7428571	0.0285714	0.1428571	0.0
		c3.4	350	75.428	1631.108	SW	44	10	13	2	0.1818182	0.1590909	0.5227273	0.1
		c3.5	550	103.721	1485.600	SW	54	15	18	4	0.2777778	0.3148148	0.3148148	0.0
		c3.6	750	161.883	1365.895	SW	45	12	14	2	0.4666667	0.1555556	0.2666667	0.1
		c3.7	950	181.268	1300.483	SW	62	17	19	4	0.2580645	0.3225806	0.2419355	0.1
		c3.8	1150				31	4	10	3	0.3870968	0.0322581	0.4193548	0.1
		c4.1	0	37.492	1505.730	S	8	4	5	0	0.5	0.25	0.25	
		c4.2	50	44.806	1476.232	S	32	9	10	1	0.09375	0.1875	0.4375	0.
		c4.3	150	57.748	1428.591	SW	35	9	12	1	0.1714286	0.1714286	0.4571429	
		c4.4	350	93.980	1342.113	S	66	13	15	3	0.1818182	0.2121212	0.4848485	0.1
		c4.5	750	137.557	1231.937	S	66	12	15	2	0.2121212	0.1212121	0.5909091	0.0
		c5.1	0	81.334	1310.071	W	34	5	5	0	0.7941176	0.0588235	0.1176471	0.0
		c5.2	50	90.848	1274.258	W	69	12	15	0	0.4347826	0.115942	0.3478261	0.1
		c5.3	150	103.889	1195.787	W	77	10	12	0	0.3636364	0.1428571	0.3766234	0.1
		c5.4	350	119.388	1111.031	SW	123	16	21	0	0.0894309	0.1626016	0.6260163	0.1
	???	c6.1	668	66.959	1076.366	W	66	7	10	0	0.530303	0	0.4242424	0.0
		c7.1	0	6.341	1755.906	W	11	3	4	0	0.7272727	0	0.0909091	0.1
		c7.2	50	9.828	1700.936	W	15	4	5	0	0.8666667	0	0.0666667	0.0
		c7.3	150	38.239	1611.476	NW	13	7	9	2	0.2307692	0.2307692	0.3846154	0.1
		c7.4	350	53.467	1481.904	NW	8	5	5	0	0.125	0.25	0.625	

c7.5	550	76.145	1361.727	N	19	6	6	0	0.1578947	0	0.7894737	0.0
c7.6	950	111.326	1184.483	SW	19	8	9	1	0.2105263	0.2105263	0.4736842	0.1
c7.7	1048	147.292	1157.979	N	42	9	11	0	0.3333333	0.047619	0.6190476	
c8.1	0	19.268	1745.546	NE	12	2	4	0	0.75	0	0.0833333	0.1
c8.2	50	20.874	1730.537	N	17	6	8	1	0.7058824	0.1176471	0.0588235	0.1
c8.3	150	29.448	1693.492	NE	5	3	4	0	0.75	0	0.25	
c8.4	0	31.073	1728.551	W	23	4	6	0	0.5652174	0.0434783	0.3913043	
c8.5	50	46.412	1715.021	SW	26	5	8	0	0.3846154	0.1538462	0.4230769	0.0
c8.6	150	50.403	1677.019	S	35	7	11	1	0.7714286	0.0857143	0.0571429	0.0
c8.7	350	137.568	1631.119	N	65	16	19	3	0.1846154	0.2769231	0.3538462	0.1
c8.8	550	154.173	1563.250	NW	25	8	11	1	0.4	0.04	0.28	
c8.9	950	233.592	1417.065	N	46	12	14	4	0.1304348	0.2173913	0.4130435	0.2
c8.10	1350	282.401	1316.063	W	79	17	19	4	0.0759494	0.2531646	0.5189873	0.1
c8.11	1750	318.935	1157.906	N	101	15	18	5	0.0594059	0.1089109	0.7425743	0.0
c9.1	0	24.717	1667.727	NW	23	8	11	1	0.4782609	0	0.3913043	0.1
c9.2	50	28.022	1634.302	NW	36	9	13	1	0.2222222	0.0555556	0.6111111	0.1
c9.3	150	35.651	1556.788	N	48	12	13	0	0.0625	0.4375	0.3541667	0.1
c9.4	350	61.893	1419.149	N	78	13	19	3	0.0897436	0.3076923	0.4487179	0.1
c9.5	550	121.081	1317.567	NW	64	14	16	2	0.125	0.0625	0.703125	0.1
c9.6	950	157.819	1194.627	N	145	13	14	0	0.0551724	0.062069	0.7655172	0.1
f1.1	0		1711.025	NW	3	1	3	0	0.3333333	0	0.3333333	0.3
f1.2	50		1691.888	NW	2	1	2	0	0.5	0	0	
f1.3	150		1653.893	NW	1	1	1	0	0	1	0	
f1.4	350		1591.402	NW	12	4	5	0	0.4166667	0.5	0	0.0
f1.5	550		1505.051	W	15	4	4	0	0.8666667	0.1333333	0	
f1.6	750		1418.671	W	16	4	5	0	0.4375	0.125	0.4375	
f1.7	950		1347.024	NW	6	4	5	0	0.6666667	0	0.3333333	
f1.8	1150		1291.390	SW	51	7	8	0	0.4117647	0.372549	0.2156863	

	f1.9	1550	919.997	SW	36	6	9	2	0.5555556	0.2777778	0.1666667	
	f1.10	1950	919.997	NE	48	6	8	1	0.0208333	0	0.9166667	0
	f1.11	2350	919.997	N	53	8	11	0	0.2264151	0.0566038	0.6037736	0.1
	f1.12	2750			6	3	4	0	0.3333333	0.5	0.1666667	
	f2.1	0	1756.969	N	12	6	8	3	0.5833333	0.0833333	0.1666667	0.1
	f2.2	50	1712.244	N	19	7	10	3	0.5263158	0.0526316	0	0.4
	f2.3	150	1589.350	N	29	10	14	4	0.3448276	0.0689655	0.3448276	0.2
	f2.4	350	1493.433	W	40	11	17	4	0.375	0.075	0.25	
	f2.5	750	1383.395	NW	62	6	9	4	0.4516129	0.1612903	0.3064516	0.0
	f2.6	1150	1293.517	NE	126	9	13	1	0.0396825	0.0714286	0.8095238	0.0
	f2.7	1550	1205.420	E	111	13	15	3	0.0630631	0.1441441	0.7477477	0.0
	f2.8	1950	1146.633	NW	114	12	15	3	0.0263158	0.3421053	0.5964912	0.0
	f2.9	2350	1094.612	NW	131	10	11	0	0.0076336	0.221374	0.6717557	0.0
needs own stream #	f2a.1	0			0	0	0	0	0	0	0	
	f3.1	0	1389.257	NW	1	1	1	0	1	0	0	
	f3.2	50	1360.123	W	12	3	6	0	0.6363636	0.2727273	0	0.0
	f3.3	150	1316.180	W	32	9	11	1	0.125	0.5625	0.28125	0.
	f3.4	350	1233.188	W	38	15	18	1	0.1842105	0.2368421	0.2894737	0.2
	f4.1	0	1474.757	SW	27	4	7	3	0.6296296	0.1111111	0.037037	0.2
	f4.2	50	1458.629	SW	32	7	10	1	0.40625	0.03125	0.53125	0.
	f4.3	150	1424.231	W	18	7	7	1	0.3888889	0.1111111	0.5	
	f4.4	350	1345.518	NW	37	9	13	2	0.1081081	0.2162162	0.5675676	0.1
	f4.5	550			39	12	13	0	0.4102564	0.1538462	0.3589744	0.0
	f4.6	950			14	3	6	0	0	0	1	
	f4.7	1350			0	0	0	0	0	0	0	
	k1.1	0			0	0	0	0	0	0	0	
	k1.2	50			5	3	5	1	0.4	0	0.4	
	k1.3	150			21	4	8	1	0.5238095	0	0.3333333	0.1

k1.4	350	62	9	13	1	0.5322581	0.2096774	0.2258065	0.0
k1.5	550	20	4	7	1	0.25	0	0.7	
k1.6	750	67	9	13	2	0.1044776	0.4776119	0.3283582	0.0
k2.1	0	2	0	1	1	1	0	0	
k2.2	50	2	0	2	2	0.5	0	0	
k2.3	150	10	5	7	1	0.5	0	0.4	
k2.4	350	51	10	13	0	0.1764706	0.1372549	0.6470588	0.0
k3.1	0	1	1	1	0	1	0	0	
k3.2	50	0	0	0	0	0	0	0	
k3.3	150	32	9	10	0	0.53125	0	0.28125	0
k3.4	350	20	8	11	0	0.5	0	0.2	
k3.5	550	59	10	15	1	0.2033898	0.1525424	0.4915254	0.1
k3.6	750	19	5	9	0	0.3157895	0	0.3157895	0.3
k4.1	0	0	0	0	0	0	0	0	
k4.2	50	3	2	3	1	0.6666667	0	0.3333333	
k4.3	150	22	6	8	1	0.5454545	0.0454545	0.2727273	0.1
k5.1	0	2	1	2	0	0	0	1	
k5.2	50	1	0	1	0	1	0	0	
k5.3	150	0	0	0	0	0	0	0	
k6.1	0	1	1	1	0	0	0	1	
k6.2	0	6	1	4	1	0.5	0	0.3333333	0.1
k6.3	100	40	9	14	1	0.4473684	0	0.3947368	0.1
k6.4	150	28	8	9	1	0.5357143	0.25	0.1071429	0.1
ky1.1	0	1	1	1	0	1	0	0	
ky1.2	50	40	6	6	0	0.15	0.325	0.425	
ky1.3	150	62	10	12	2	0.3064516	0.1935484	0.3225806	0.1
ky1.4	350	54	12	12	0	0.4074074	0	0.3703704	0.2
ky1.5	550	83	12	15	2	0.4337349	0.0120482	0.313253	0.24
ky2.1	0	34	3	4	1	0.9705882	0	0	0.0
ky2.2	50	7	4	4	0	0.8571429	0	0	0.14
ky2.3	150	54	5	6	0	0.9259259	0	0	0.0
ky2.4	350	70	13	14	1	0.6571429	0	0.2428571	

ky3.1	0				0	0	0	0	0	0	0	
ky3.2	50				23	8	10	0	0.3913043	0.0434783	0.5652174	
ky3.3	150				61	14	17	1	0.2459016	0	0.5737705	0.1
ky3.4	350				57	16	18	1	0.2631579	0.0350877	0.4561404	0.2
ky3.5	550				106	14	16	0	0.245283	0.0566038	0.4811321	0.2
p1.1	0				1	1	1	0	0	0	1	
p1.2	50				8	1	1	0	1	0	0	
p1.3	150				20	4	5	0	0.4	0	0.55	
p1.4	350				24	7	12	1	0.2916667	0	0.3333333	
p1.5	0				5	2	3	0	0.8	0	0	
p1.6	50				23	8	11	1	0.3043478	0	0.3478261	0.3
p1.7	150				29	9	11	2	0.4482759	0.0344828	0.3448276	0.1
p2.1	0				2	1	2	0	1	0	0	
p2.2	50				1	0	1	0	0	0	0	
p2.3	150				31	8	12	1	0.6129032	0	0.2580645	0.1
p2.4	350				36	8	14	3	0.5555556	0.0277778	0.1666667	
p3.1	0				4	2	3	0	0	0	0	
p3.2	50				2	0	2	1	0.5	0	0	
p3.3	150				27	14	18	2	0.4074074	0.037037	0.3333333	0.2
p3.4	350				23	7	8	1	0.6521739	0	0.1304348	0.2
p3.5	550				34	9	12	0	0.3333333	0.1212121	0.4848485	0.0
p3.6	750				50	16	18	1	0.28	0.12	0.44	
r1.1	0	96.704	2283.912	SW	52	7	10	2	0.6730769	0	0.1538462	0.1
r1.2	50	102.344	2255.362	SW	96	13	17	2	0.6041667	0.0208333	0.28125	0.
r1.3	150	110.183	2205.249	SW	65	9	16	1	0.4126984	0.031746	0.4444444	0.1
r1.4	350	145.198	2143.726	SW	86	12	19	4	0.2235294	0.0470588	0.2941176	0.4
r1.5	550	172.274	2093.183	SE	63	15	18	3	0.2380952	0.047619	0.4444444	0.2
r1.6	950	204.947	2017.659	S	51	9	15	5	0.1960784	0	0.5294118	0.2
r2.1	0	163.911	2071.656	SW	43	8	13	1	0.7209302	0	0.1627907	0.1
r2.2	50	170.558	2058.091	NW	55	12	18	2	0.4363636	0.0727273	0.2545455	0.2

	r2.3	150	175.006	2033.561	W	53	9	15	3	0.3921569	0.1568627	0.2745098	0.1
	r2.4	350	292.121	2004.828	SE	61	10	14	2	0.2280702	0.1052632	0.4736842	0.1
	r2.5	550	315.559	1986.011	W	70	15	21	3	0.1571429	0.0285714	0.6857143	0.1
	r2.6	950	405.462	1945.781	SW	128	16	22	3	0.484375	0.015625	0.34375	0.
	r2.7	1350	523.652	1909.670	SE	106	18	22	3	0.1509434	0.0283019	0.5660377	0.2
	r2.8	1750	564.863	1860.997	S	109	22	27	4	0.1192661	0.0642202	0.6146789	0.2
	r3.1	0	9.594	2311.721	NW	30	6	9	0	0.7	0	0.1333333	0.1
	r3.2	50	10.836	2272.649	NW	36	8	11	0	0.4285714	0	0.2571429	0.3
	r3.3	150	27.083	2222.436	NW	69	13	17	1	0.1940299	0.0447761	0.4029851	0.3
	r3.4	350	73.823	2137.232	NW	37	9	16	1	0.3142857	0.0857143	0.3428571	0.2
no benthic sample	r3.5	504	79.704	2075.071	NW								
	r4.1	0	40.513	2230.946	SW	24	5	8	1	0.3333333	0	0.4166667	
	r4.2	50	45.955	2199.105	S	21	6	9	2	0.7	0.05	0.15	
	r4.3	150	56.735	2145.420	S	34	9	12	2	0.6470588	0	0.2058824	0.1
	r4.4	350	77.628	2054.154	SW	39	9	16	3	0.5526316	0.0789474	0.1842105	0.1
	r4.5	550				30	6	11	2	0.3448276	0	0.5517241	0.1
	r4.6	950				68	11	17	3	0.4558824	0.0294118	0.3235294	0.1
	r5.1	0	53.917	2179.944	S	15	7	9	1	0.8	0	0	
	r5.2	50	55.962	2131.019	SW	29	7	10	1	0.5862069	0	0.3448276	0.0
	r5.3	150	85.491	2073.055	E	45	10	15	2	0.4	0	0.2888889	0.3
	r5.4	350	95.486	1990.316	SE	54	12	19	4	0.2962963	0	0.4814815	0.2
	x1.1	0	9.174	998.629	E	1	0	1	0	0	0	0	
	x1.2	50	11.355	971.880	NE	19	6	8	3	0.3684211	0.2631579	0.1578947	0.2
	x1.3	150	38.623	945.059	NE	12	3	6	2	0.6666667	0	0.25	0.0
	x1.4	350	63.642	896.621	SE	34	10	10	1	0.4705882	0	0.4411765	0.0
	x1.5	550	102.790	852.261	SE	70	14	17	1	0.3142857	0	0.6142857	0.0

x1.6	950	176.520	784.673	S	63	11	12	0	0.1111111	0	0.7301587	0.1
x1.7	1350	232.285	725.454	E	31	8	12	1	0.3666667	0.0333333	0.4	
y1.1	0				13	2	3	0	0.9230769	0	0	0.0
y1.2	50				6	2	3	0	0.1666667	0.5	0.3333333	
y1.3	150				75	8	11	2	0.1733333	0.0933333	0.6	0.1
y1.4	350				62	9	11	1	0.1451613	0.0483871	0.7419355	0.0
y1.5	550				49	10	13	2	0.0204082	0.0816327	0.5714286	0.3
y1.6	950				73	10	11	0	0.0547945	0	0.6849315	0.2
y1.7	1350				88	10	12	0	0.0568182	0.0568182	0.6363636	
y2.1	0				0	0	0	0	0	0	0	
y2.2	50				4	1	3	0	0.5	0	0.5	
y2.3	150				53	10	11	0	0.245283	0	0.4339623	0.3
y2.4	350				113	12	16	2	0.0619469	0	0.7522124	0.1
y2.5	550				79	9	13	2	0.2531646	0.0126582	0.5189873	0.2

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Flow Origin, Drainage Area, and Hydrologic Characteristics for Headwater Streams in the Mountaintop Coal-Mining Region of Southern West Virginia, 2000–01

Water-Resources Investigations Report 02-4300

In cooperation with the
U.S. Office of Surface Mining and the
U.S. Environmental Protection Agency

U.S. Department of the Interior
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By KATHERINE S. PAYBINS

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Charleston, West Virginia
2003

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CONVERSION FACTORS, DATUMS, WATER-QUALITY ABBREVIATIONS, AND ACRONYMS

CONVERSION FACTORS

Multiply	By	To obtain
acre	0.00404686	square kilometer
cubic feet per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
inch (in.)	25.4	millimeter

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F), and conversely, by the following equations:

°F = (1.8)°C + 32 °C = (°F-32)/1.8

Water year is calculated from October of calendar year one through September of calendar year two.

DATUMS

In this report, vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88), and horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83). Historical data collected and stored as National Geodetic Vertical Datum of 1929 have been converted to North American Vertical Datum of 1988 (NAVD 88) for this publication.

WATER-QUALITY ABBREVIATIONS

Specific conductance of water is expressed in microsiemens per centimeter at 25°C (µS/cm). This unit is equivalent to micromhos per centimeter at 25°C (µmho/cm), formerly used by the U. S. Geological Survey.

ACRONYMS

EPA	U.S. Environmental Protection Agency
MTRM EIS	Mountaintop Removal Coal Mining Environmental Impact Statement
OSM	U.S. Office of Surface Mining and Reclamation
SMCRA	Surface Mining Control and Reclamation Act
USGS	U.S. Geological Survey
WVDEP	West Virginia Department of Environmental Protection

U.S. Department of the Interior
GALE A. NORTON, Secretary

U.S. Geological Survey
Charles G. Groat, Director

For additional information write to:

Chief, West Virginia District
U.S. Geological Survey
11 Dunbar Street
Charleston, WV 25301

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225-0286

Flow Origin, Drainage Area, and Hydrologic Characteristics for Headwater Streams in the Mountaintop Coal-Mining Region of Southern West Virginia, 2000–01

By Katherine S. Paybins

Abstract

Characteristics of perennial and intermittent headwater streams were documented in the mountaintop removal coal-mining region of southern West Virginia in 2000–01. The perennial-flow origin points were identified in autumn during low base-flow conditions. The intermittent-flow origin points were identified in late winter and early spring during high base-flow conditions.

Results of this investigation indicate that the median drainage area upstream of the origin of intermittent flow was 14.5 acres, and varied by an absolute median of 3.4 acres between the late winter measurements of 2000 and early spring measurements of 2001. Median drainage area in the northeastern part of the study unit was generally larger (20.4 acres), with a lower median basin slope (322 feet per mile) than the southwestern part of the study unit (12.9 acres and 465 feet per mile, respectively). Both of the seasons preceding the annual intermittent flow visits were much drier than normal. The West Virginia Department of Environmental Protection reports that the median size of permitted valley fills in southern West Virginia is 12.0 acres, which is comparable to the median drainage area upstream of the ephemeral-intermittent flow point (14.5 acres). The maximum size of permitted fills (480 acres), however, is more than 10 times the observed maximum drainage area upstream of the ephemeral-intermittent flow point (45.3 acres), although a single valley fill may cover more than one drainage area.

The median drainage area upstream of the origin of perennial flow was 40.8 acres, and varied by an absolute median of 18.0 acres between two annual autumn measurements. Only basins underlain with mostly sandstone bedrock produced perennial flow. Perennial points in the northeast part of the study unit had a larger median drainage area (70.0 acres) and a smaller median basin slope (416 feet per mile) than perennial points in the southwest part of the study unit (35.5 acres and 567 feet per mile, respectively). Some streams were totally dry for one or both of the annual October visits. Both of the seasons preceding the October visits had near normal to higher than normal precipitation. These dry streams were adjacent to perennial streams draining similarly sized areas, suggesting that local conditions at a first-order-stream scale determine whether or not there will be perennial flow.

Headwater-flow rates varied little from year to year, but there was some variation between late winter and early spring and autumn. Flow rates at intermittent points of flow origin ranged from 0.001 to 0.032 cubic feet per second, with a median of 0.017 cubic feet per second. Flow rates at perennial points of flow origin ranged from 0.001 to 0.14 cubic feet per second, with a median of 0.003 cubic feet per second.

INTRODUCTION

The surface mining of coal by means of mountaintop removal results in excess rock material (spoil), some of which is placed in headwater valleys adjacent to the mined area. The Code of Federal Regulations, crafted by the U.S. Office of Surface Mining and Reclamation (OSM), describes conditions for the placement of excess spoil in headwater valleys (valley fills) (Legal Information Institute, 2002a, 2002b). The 1999 and 2002 U.S. District court rulings interpret Surface Mining Control and Reclamation Act (SMCRA) and Clean Water Act regulations to allow the placement of valley fill material only in ephemeral streams and not within 100 feet of intermittent and perennial streams, unless the post-mining land use is designated as development (U.S. District Court for the Southern District of West Virginia, 1999). Coal-mining interests and some government leaders are concerned that if this rule is enforced, mountaintop-removal mining will cease to be feasible in West Virginia.

Five Federal and State agencies began cooperation on a Mountaintop Removal Coal Mining Environmental Impact Statement (MTRM EIS) in 1999 as a voluntary response to the court challenge dealing with SMCRA and the Clean Water Act mountaintop-removal enforcement issues.

Part of the MTRM EIS will assess the environmental effects on waters of the United States and on biota (U.S. Environmental Protection Agency, 1999). In support of this objective, the U.S. Geological Survey (USGS), in cooperation with OSM and the U.S. Environmental Protection Agency (EPA), reported the point of flow origins for perennial and intermittent headwater streams in the coal-mining region of southern West Virginia, and studied their hydrologic and drainage-area characteristics.

Purpose and Scope

This report describes the hydrologic and drainage area characteristics of intermittent and perennial headwater streams in southern West Virginia that were not affected by mining. The streams were examined in late winter or early spring (February through April), when the water table is at its highest elevation, and in autumn (October), when the water table is at its lowest elevation. The origin of continuous base flow was identified in 36 unmined headwater streams in southern West Virginia in February–April and October of both 2000 and 2001. Methods were developed to identify the origin of continuous base flow in hydrologic terms, and drainage-area characteristics were determined, including variations in drainage-area sizes upstream of flow-origin points over time. A better understanding of the relations between ephemeral, intermittent, and perennial headwater streams and their drainage-area characteristics will help regulators make sound decisions on valley-fill permits in West Virginia and adjacent states with similar issues.

Description of Study Area

Fifteen percent of the Nation’s coal produced in 2000 was mined in West Virginia, and West Virginia leads the United States in coal exports (West Virginia Office of Miners' Health, Safety and Training, 2000). Coal is mined by means of both underground and surface methods. In recent years, it has become both economically and technologically possible to remove entirely multiple, thin layers of coal near the tops of the mountains. This type of mining is called mountaintop-removal mining. Large-scale mountaintop-removal mines generate excess fragmented rock material in the mining process that cannot be replaced at the top of the mountain once the coal is removed. This excess spoil is placed in valleys adjacent to the surface mines. West Virginia has approximately 1,700 valley fills ranging in size from less than 1 acre to 480 acres and with a median size of 12.0 acres (West Virginia Department of Environmental Protection, 2002). The streams in the study described here are within the region of mountaintop-removal mining, but had not yet been filled at the start of this work.

The 36 first-order stream sites are grouped within five study areas in the Appalachian Plateaus Physiographic Province in southern West Virginia (fig. 1), which is characterized by mountainous terrain (Fenneman, 1938; Fenneman and Johnson, 1946). The streams of the Appalachian Plateaus have eroded sedimentary rocks into steeply sloping hills and narrow valleys. A thin layer of regolith commonly overlies interbedded sandstone, conglomerate, siltstone, shale, coal, limestone, and dolomite rocks, all of which

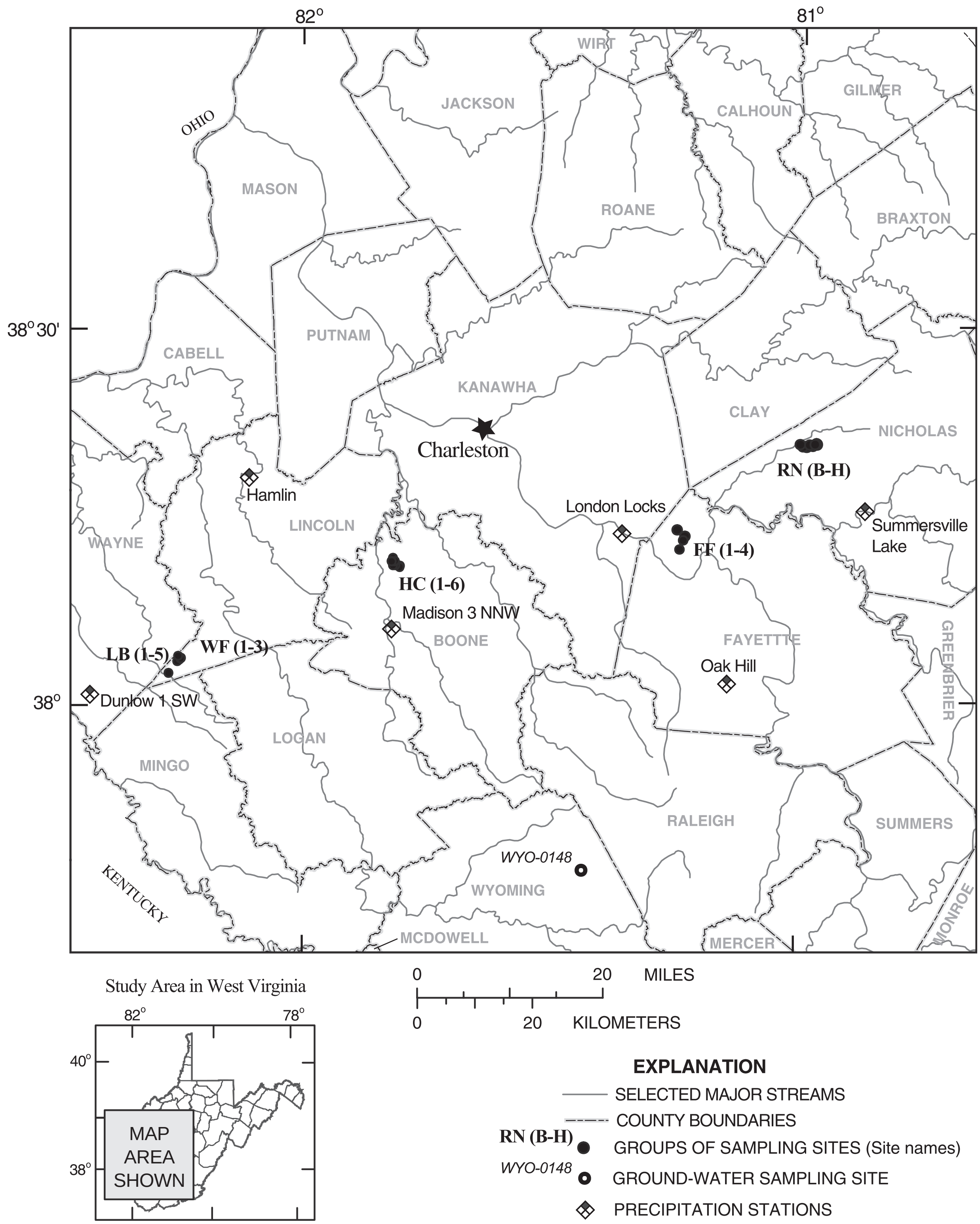

Figure 1. Locations of the study-area groups of sampling sites in the headwater streams of the mountaintop coal-mining region of southern West Virginia, 2000–01.

dip gently to the northwest across the region. Resistant bedrock exposed at the highest elevations (headwater regions) is most commonly sandstone or shale, but the thickness of this cap-rock layer is variable (Fenneman, 1938; Fenneman and Johnson, 1946; and U.S. Geological Survey, 1970). Most ground water flows along the valley walls through a series of fractures composed of joints, faults, and bedding planes, and in slump fractures (Wyrick and Borchers, 1981).

The climate of West Virginia is continental, with four distinct seasons and a large temperature variation between summer and winter (U.S. Department of Commerce, 1960; Messinger and Hughes, 2000). Mean monthly summer temperatures are about 65-75°F, while mean monthly winter temperatures are about 25-40 °F; these temperatures depend on elevation. Prevailing winds move generally from west to east. Due to local orographic uplift, the heaviest precipitation falls on the windward (southwest and western) sides of mountains, which have rain shadows on their leeward (northeast and eastern) sides. Throughout the warmer months, the region is affected by northeast-moving, moisture-laden maritime tropical air that produces spatially discrete showers and thunderstorm cells (U.S. Department of Commerce, 1960). In the colder part of the year, large low-pressure storms deliver precipitation over broader regions, but less total precipitation than warm-weather storms.

In general, the 2000 water year was drier than average, and the 2001 water year was an average year for precipitation and ground-water levels (Ward and others, 2001, 2002) (fig. 2). The October–March periods in both 2000 and 2001 were much drier than the 30-year average at all examined precipitation stations in southwestern West Virginia (U.S. Department of Commerce, 2000, 2001, and 2002a) (table 1). Precipitation at various stations in the period (April–September) preceding the October 2000 field work range from about 4 to 11 in. above normal. In the period preceding the October 2001 field work, precipitation was below normal at Dunlow and Madison (3.9 in. and 2.11 in., respectively), and 0.2–5.8 in. above normal at the other stations. In the northeast part of the study area, average annual precipitation is 1.8 in. greater than in the southwest part of the study area.

Table 1. Precipitation data for long-term National Oceanic and Atmospheric Administration monitoring sites within and adjacent to headwater streams in the mountaintop coal-mining region of southern West Virginia, 2000–01

[**Group of sites closest to precipitation station:** See figure 1 for site locations and names. **Normal monthly precipitation:** Totals calculated from U.S. Department of Commerce data from 1971–2000; precipitation data are in inches]

Precipitation station	Group of sites closest to precipitation station	October 1999 through March 2000	April 2000 through September 2000	October 2000 through March 2001	April 2001 through September 2001	Normal monthly precipitation		Normal annual precipitation
						October–March	April–September	
Dunlow 1 SW	LB, WF	10.06	29.69	[1]4.83	20.96	20.86	24.85	45.71
Hamlin	HC, LB, WF	19.56	27.95	[1]8.96	24.47	20.14	24.26	44.40
London Locks	FF	15.85	36.30	12.38	29.19	19.76	25.50	45.26
Madison 3 NNW	HC	12.55	31.76	[1]10.18	[1]25.00	20.73	27.11	47.84
Oak Hill	FF	11.95	33.86	11.25	30.69	20.62	25.59	46.21
Summersville Lake	RN	12.94	36.93	12.10	32.61	20.65	26.83	47.48

[1]One to nine days of precipitation data are missing for at least one month during the given time interval.

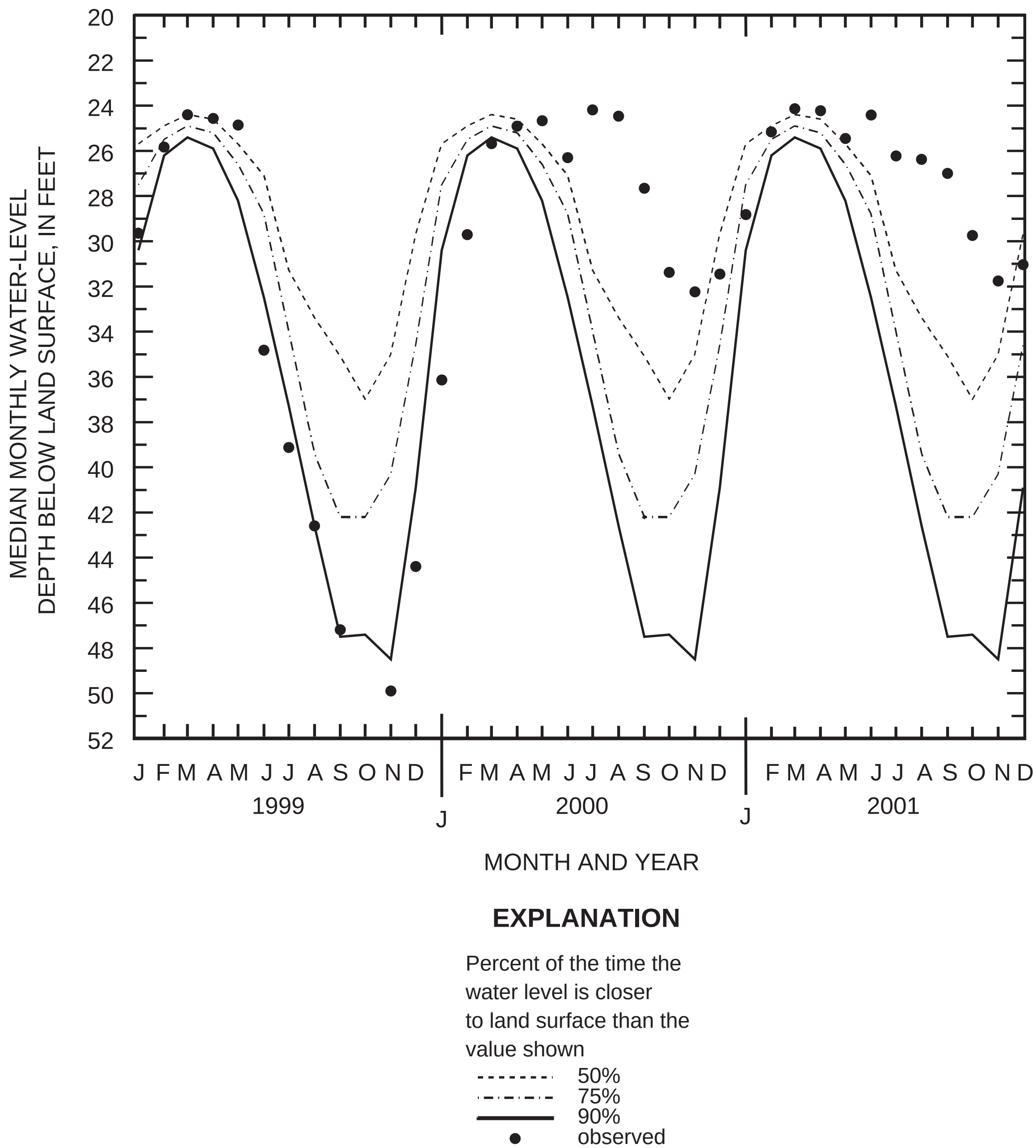

Figure 2. Observed median monthly water levels for 1999–2001 and monthly water-level statistics for 1976–2001 at U.S. Geological Survey monitoring well WYO-0148 in Twin Falls State Park, Wyoming County, West Virginia.

Definitions of Perennial, Intermittent, and Ephemeral Streams

Water in the environment is available in the air, in precipitation, in the ground, and on the land surface. The interface where the ground-water table intersects the land surface and becomes streamflow in a headwater channel is the point of flow origin. Streamflow derived from ground water alone is called base flow. Overland and near-surface flow contributing to streamflow are called surface and subsurface storm runoff (Black, 1991). When a stream receives base flow year-round, it is considered to be a perennial stream (fig. 3). Intermittent flow indicates a seasonal lowering of the water table during the summer and early autumn, as base-flow contributions to the channel cease. If a channel does not intersect the water table at any time of year, it is considered to be an ephemeral channel.

Given the natural hydrologic cycle, three basic types of definitions for perennial, intermittent, and ephemeral streamflow exist. Descriptive definitions are often obtained from cartographers, whose maps are used frequently in a legal and regulatory environment. Hydrologic definitions are based on observations and measurements of hydrologic phenomena, such as the relations between stormwater flow and ground water, and have recently been relied on more often in regulations. Biologic definitions combine the existence or absence of indicator species of benthic invertebrates with hydrologic phenomena.

Much research has focused on the stream-type, blue-line symbol on USGS maps at the 1:24,000 scale, in spite of the fact that the line symbol on these maps is not based on hydrologic criteria (Leopold, 1994). Even so, many state and local laws specifically state that this map series should be used when making any regulatory decisions. Specific topographic instructions to past USGS cartographers (U.S. Geological Survey, 1980) state that:

1. "…all perennial streams are published regardless of length."
2. "All intermittent streams are published that are longer than 2,000 feet" and
3. "In general, headwater drainage shown on the published map should terminate no higher than about 1,000 feet from the divide, or at the upper confluence of streams, whichever appears most appropriate."

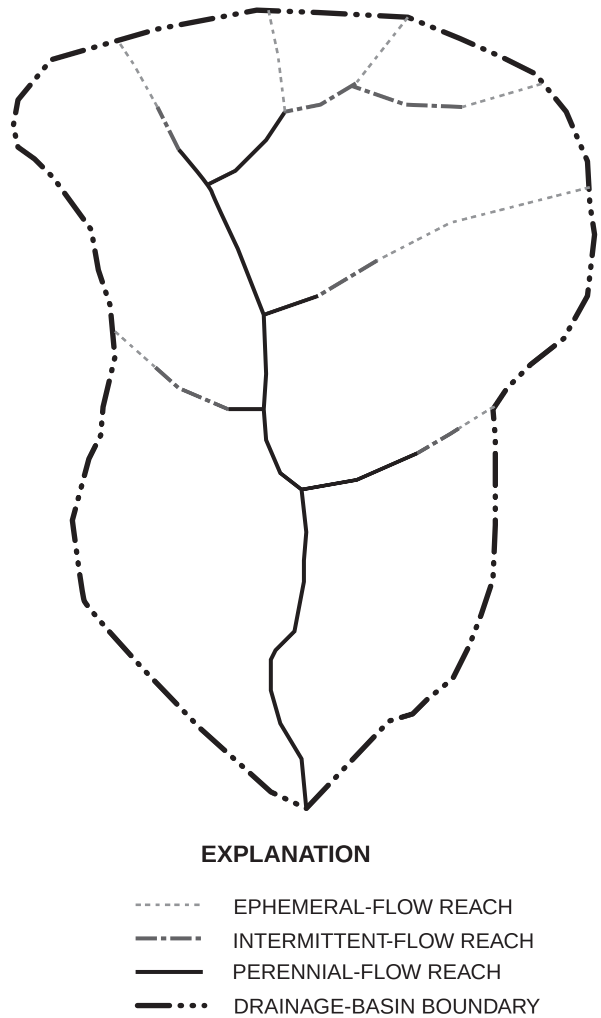

Figure 3. Ephemeral-, intermittent-, and perennial-flow patterns typical for the mountaintop coal-mining region of southern West Virginia.

These instructions indicate that headwater limits of blue lines on maps do not reflect actual field conditions. Generally, a far larger number of actual channels can be identified on the ground than are visible on a published map (Leopold, 1994). For instance, the topographic maps used in this study showed that only 12 of the headwater drainage areas had intermittent streams; but in this study, 36 headwater drainage areas were identified that had intermittent or perennial streams. Twelve of those 36 streams had intermittent flow, but no perennial flow in 2000 or 2001.

Hydrologic definitions of perennial, intermittent, or ephemeral streamflow in the eastern U.S. are based on the relations between stormwater and ground water, the timing and duration of continuous base flow, drainage area, channel characteristics, and presence or absence of substrate bedforms indicative of flowing waters (Hewlett, 1982; Stefania Shamet, U.S. Environmental Protection Agency, Region 3, written commun., 1999). A basic hydrologic definition, and the one used in this study, is modified from Langbein and Iseri (1960). A perennial stream is one that flows continuously, and thus has flow from both ground-water discharge and surface runoff. An intermittent stream flows only at certain times in the year, when it receives both ground-water discharge and storm runoff. Ephemeral streams flow only in direct response to surface runoff of precipitation or melting snow, and their channels are at all times above the water table. The West Virginia Department of Environmental Protection (WVDEP), Water Quality Standard CSR 46-1-1-2.9, defines intermittent streams as “streams which have no flow during sustained periods of no precipitation, and which do not support aquatic life whose life history requires residence in flowing water for a continuous period of at least 6 months”. OSM regulations define an intermittent stream as a “stream or part of a stream that flows continuously for at least 1 month of the calendar year as a result of ground-water discharge or surface runoff; the term does not include a stream that flows for less than one month of a calendar year, and then only in direct response to precipitation in the immediate drainage area and whose channel bottom is always above the local water table.” (Legal Information Institute, 2002a). Pennsylvania regulation 25 Pa. Code ϕ 87.1 includes a reference to channel substrate indicative of flowing water, or lack thereof, to further differentiate ephemeral from intermittent streams (Stefania Shamet, U.S. Environmental Protection Agency, Region 3, written commun., 1999).

Biologic interpretations of perennial, intermittent, and ephemeral streams are changing with increasing knowledge of benthic invertebrates and water-obligate fauna in headwater environments. Some taxa that are now known to be present in intermittent streams are currently used as indicators of continuous (perennial) flow (M.E. Passmore, U.S. Environmental Protection Agency, Region 3, written commun., 2002). A growing body of literature indicates that intermittent flows can support a diverse and abundant invertebrate and salamander assemblage (Feminella, 1996; Williams, 1996; Dietrich and Anderson, 2000; M.E. Passmore, written commun., 2002).

Acknowledgments

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STUDY DESIGN AND DATA COLLECTION

A multi-agency group, including the WVDEP, USGS, and OSM, selected 43 headwater streams for investigation from mountaintop-removal-mine permit maps. At each of these first-order streams, permits for filling with excess mining spoil were either pending or approved. Although 12 of the 43 drainage areas were shown on USGS 1:24,000-scale topographic maps as including intermittent streams, field inspections during this study showed that 36 of these drainage areas included intermittent or perennial streams. The 36 of 43 headwater streams evaluated for this study are in unmined drainage areas in Boone, Fayette, Lincoln, and Nicholas Counties, in the heart of the surface coal-mining region of southern West Virginia (fig. 1). Surface-mining activities precluded further visits to some basins. Some sites were not visited due to clearing of most vegetation in preparation for filling. Clearcutting significantly alters the hydrologic regime of a watershed by decreasing evapotranspiration and increasing surface and subsurface runoff (Helvey and Patric, 1965; Black, 1991; Fitzpatrick and others, 1998).

Each of the headwater streams was visited in February 2000, October 2000, March-April 2001, and October 2001 in order to identify the point of origin of continuous surface flow. Multi-agency teams made the February 2000 visit, while a USGS team made the next three visits. The point where base flow begins in the late winter or early spring corresponds to the highest water-table elevation, and is the point of intermittent-flow origin, or the boundary between ephemeral and intermittent flow (called the intermittent point). The point where base flow begins in the late summer and early autumn corresponds to the lowest water-table elevation, and is the point of perennial flow origin, or the boundary between intermittent and perennial flow (called the perennial point).

The field work done in February–April was timed to coincide with the wettest part of the year, with little evapotranspiration before leaf-out begins, and a ground-water table normally at its highest annual elevation in the region (fig. 2). The February–April field work thus documented the point of origin of continuous intermittent base flow (intermittent point) under conditions of no rainfall and subsequent storm runoff. Many streams throughout West Virginia have minimum base flows in late summer through early autumn, and maximum base flows in late winter or early spring (Ward and others, 2002). Different teams with different equipment visited each group of sites (FF, HC, LB, RN, WF) in February 2000. The accuracy of some of the global-positioning-systems (GPS receivers) varied between each group, and a few intermittent-point designations were mapped approximately for some sites, which may have introduced an immeasurable error for a few intermittent points. Project-planning complications delayed the 2001 site visits, and some understory plants were already leafed out during the April visits. The evapotranspiration from these plants probably had some effect on the measured variables.

October field work was timed before leaf-off to coincide with the dry conditions and the lowest water-table elevations generally observed in early autumn in the region (fig. 2). October field work thus documented the point of origin of continuous perennial base flow (perennial point), under conditions of no rainfall and subsequent storm runoff. There was no base flow in 20 headwater streams in October of either 2000 or 2001, and 12 streams contained no perennial flow in either 2000 or 2001 (table 2).

For each site, the field crew walked the full length of the stream channel to determine the location of the upstream limit of continuous surface flow. The geographic coordinates of the point or zone where streamflow was observed to be continuous in the channel and no flow was upstream were identified with a Precision Lightweight GPS Receiver (PLGR). The error in horizontal location for the PLGR system is 13 ft. If the GPS could not acquire a location for the upstream flow limit, a Bushnell rangefinder, with an error of 3 ft, was used to estimate the distance from a point where a GPS reading was acquired.

All visits included measurements of streamflow, water temperature, and specific conductance, except for the February 2000 visits (they were not included in the original study design). Streamflow was measured within 15 ft downstream of the flow origin point with one of three methods. A pygmy meter was used to measure flow velocity across a defined channel width when the channel was wide and deep enough for the meter. Floatable material was timed over a set distance to measure velocity when the channel was not deep enough to use the pygmy meter. The flow at a few sites was measured by timing the filling of a bucket of known volume. Water temperature was measured to help determine whether or not surface water contributed in a major way to the flow. (Surface-water temperature is generally higher than ground-water temperature in summer and lower in winter.) For autumn visits, when warmer water temperatures indicated possible upstream flow through channel sand or gravel deposits, the point of flow origin was reevaluated by hiking upstream to verify that no surface flow existed. Specific conductance was measured as a possible indicator of mine-water discharge, which generally has higher specific conductance than natural ground water. Conductance values measured in the field differed widely, however, despite the absence of coal mining upstream of the study sites.

To avoid the effects of stormwater runoff, streams were evaluated only if precipitation exceeding 0.1 in. was not recorded for at least 1 day prior to the visit (table 2). A continuous streamflow-gaging station (03204210) was operated during this study on a small, unmined headwater-stream site on Spring Branch near Mud, WV. The record from that station indicates that in both the spring and autumn of 2000, stormwater flow in a headwater basin (0.53 mi^2) generally passed the stream-gaging station within 24 hours of a precipitation event of less than 0.6 in. (fig. 4).

The drainage areas for the headwater-stream sites were assumed to be forested and previously undisturbed by deep or surface coal-mining activity. Because it was later discovered that surface mining likely had affected 7 of the original 43 headwater streams, they are not included in the following analysis of 36 sites (table 2). Six of the streams in McDowell County were accessible from a bench of a 1970s contour mine. The origin of flow for all six streams for all visits was at or near the base of the rubble pile downgradient from the mine bench. One Nicholas County headwater stream was dry during all visits, and there was no

Table 2. Location and drainage area of intermittent and perennial points in headwater streams in the mountaintop coal-mining region of southern West Virginia, 2000–01

[**Sampling site:** See figure 1 for site locations and names. *****, No continuous flow identified in drainage area. ******, Drainage area unavailable due to preparation for or actual filling with coal-mining spoil. *****,** Drainage area not visited during field season. ******,** Intermittent or perennial point identified upstream in one or more tributary valleys. *******,** Perennial point identified downstream of two intermittent tributaries. --, not applicable; <, actual value is less than value shown]

Sampling site	2000 Intermittent point				2001 Intermittent point				2000 Perennial point				2001 Perennial point			
	Drainage area, in acres	Latitude	Longitude	Minimum number of days since rain	Drainage area, in acres	Latitude	Longitude	Minimum number of days since rain	Drainage area, in acres	Latitude	Longitude	Minimum number of days since rain	Drainage area, in acres	Latitude	Longitude	Minimum number of days since rain
FF1	19.4	38.1686	81.2498	4	8.1	38.1675	81.2495	2	*	--	--	5	**	--	--	--
FF1a	***	--	--	--	18.3	38.1786	81.2559	2	*	--	--	5	**	--	--	--
FF3	10.8	38.1829	81.2434	5	19.0	38.1833	81.2440	2	65.0	38.1852	81.2490	5	122.3	38.1870	81.2514	5
FF4	45.3	38.1898	81.2390	5	52.5	38.1889	81.2402	2	***	--	--	5	98.2	38.1886	81.2418	5
HC1a	12.0	38.1415	81.8027	1	15.0	38.1415	81.8029	1	54.0	38.1406	81.8056	2	28.5	38.1413	81.8035	2
HC1b	24.4	38.1390	81.8037	1	31.8	38.1394	81.8041	1	40.7	38.1402	81.8055	2	35.3	38.1396	81.8046	2
HC2	26.5	38.1418	81.8126	1	22.2	38.1420	81.8121	1	47.3	38.1406	81.8136	2	19.7	38.1412	81.8131	2
HC3a	***	--	--	--	24.2	38.1438	81.8185	1	23.4	38.1439	81.8183	2	24.1	38.1439	81.8185	2
HC3b	13.8	38.1420	81.8173	1	*	--	--	1	40.8	38.1436	81.8183	2	22.8	38.1431	81.8178	2
HC4	****	--	--	--	****	--	--	--	****	--	--	--	23.0	38.1481	81.8206	2
HC4a	8.4	38.1486	81.8194	1	7.7	38.1486	81.8193	1	10.4	38.1484	81.8197	2	*****	--	--	--
HC4b	9.2	38.1478	81.8197	1	7.7	38.1478	81.8195	1	*	--	--	2	*****	--	--	--
HC5	9.6	38.1532	81.8167	1	*	--	--	1	*	--	--	2	*	--	--	2
HC6a	16.4	38.1476	81.8130	1	19.7	38.1481	81.8130	1	*	--	--	--	20.7	38.1485	81.8132	2
HC6b	18.0	38.1487	81.8134	1	17.9	38.1488	81.8137	1	*	--	--	--	18.0	38.1486	81.8133	2
LB1	***	--	--	--	10.8	37.9766	82.2724	1	*	--	--	10	*	--	--	2
LB2	***	--	--	--	12.7	37.9734	82.2670	1	*	--	--	10	*	--	--	2
LB3	***	--	--	--	17.7	37.9748	82.2632	2	52.0	37.9723	82.2622	10	*	--	--	2
LB4	7.9	37.9722	82.2589	3	10.1	37.9721	82.2585	2	*	--	--	10	*	--	--	2
LB5	***	--	--	--	13.1	37.9760	82.2586	1	34.0	37.9749	82.2570	10	34.8	37.9746	82.2572	2
RNB	11.3	38.3304	80.9854	2	**	--	--	--	**	--	--	--	**	--	--	--
RNC	40.6	38.3298	80.9981	1	***	--	--	--	44.2	38.3296	80.9983	4	66.5	38.3279	80.9991	1
RND	8.9	38.3293	81.0051	<1	13.3	38.3293	81.0057	2	*	--	--	4	*	--	--	1
RNE	30.6	38.3329	81.0106	1	43.2	38.3331	81.0127	2	*	--	--	2	66.1	38.3324	81.0158	1
RNF	19.4	38.3326	80.9920	1	23.2	38.3331	80.9920	8	41.9	38.3341	80.9922	2	*	--	--	1

Table 2. Location and drainage area of intermittent and perennial points in headwater streams in the mountaintop coal-mining region of southern West Virginia, 2000–01—*Continued*

Sampling site	2000 Intermittent point				2001 Intermittent point				2000 Perennial point				2001 Perennial point			
	Drainage area, in acres	Lati-tude	Longi-tude	Minimum number of days since rain	Drainage area, in acres	Lati-tude	Longi-tude	Minimum number of days since rain	Drainage area, in acres	Lati-tude	Longi-tude	Minimum number of days since rain	Drainage area, in acres	Lati-tude	Longi-tude	Minimum number of days since rain
RNG1	20.4	38.3329	80.9773	2	27.5	38.3331	80.9790	8	27.6	38.3332	80.9790	4	27.5	38.3332	80.9790	1
RNG2	31.4	38.3345	80.9787	2	28.0	38.3349	80.9779	8	***	--	--	--	28.4	38.3349	80.9781	1
RNG3	22.2	38.3329	80.9812	2	22.2	38.3329	80.9814	8	22.2	38.3329	80.9816	4	28.6	38.3336	80.9812	1
RNH	***	--	--	--	40.7	38.3396	80.9772	8	125.9	38.3428	80.9799	4	150.1	38.3439	80.9820	1
WF1a	14.5	37.9907	82.2377	3	24.7	37.9898	82.2368	8	*	--	--	10	*	--	--	2
WF1b	6.3	37.9881	82.2408	3	10.1	37.9880	82.2399	8	*	--	--	10	*	--	--	2
WF2a	10.7	37.9928	82.2347	3	10.7	37.9927	82.2348	8	*	--	--	10	*	--	--	2
WF2b1	15.9	37.9937	82.2330	3	14.9	37.9938	82.2331	8	*	--	--	10	*	--	--	2
WF2b2	22.2	37.9933	82.2344	3	21.2	37.9933	82.2346	8	*	--	--	10	*	--	--	2
WF3a	***	--	--	--	7.9	37.9966	82.2388	8	*	--	--	10	*	--	--	2
WF3b	10.9	37.9964	82.2394	3	12.1	37.9967	82.2393	8	*	--	--	10	*	--	--	2

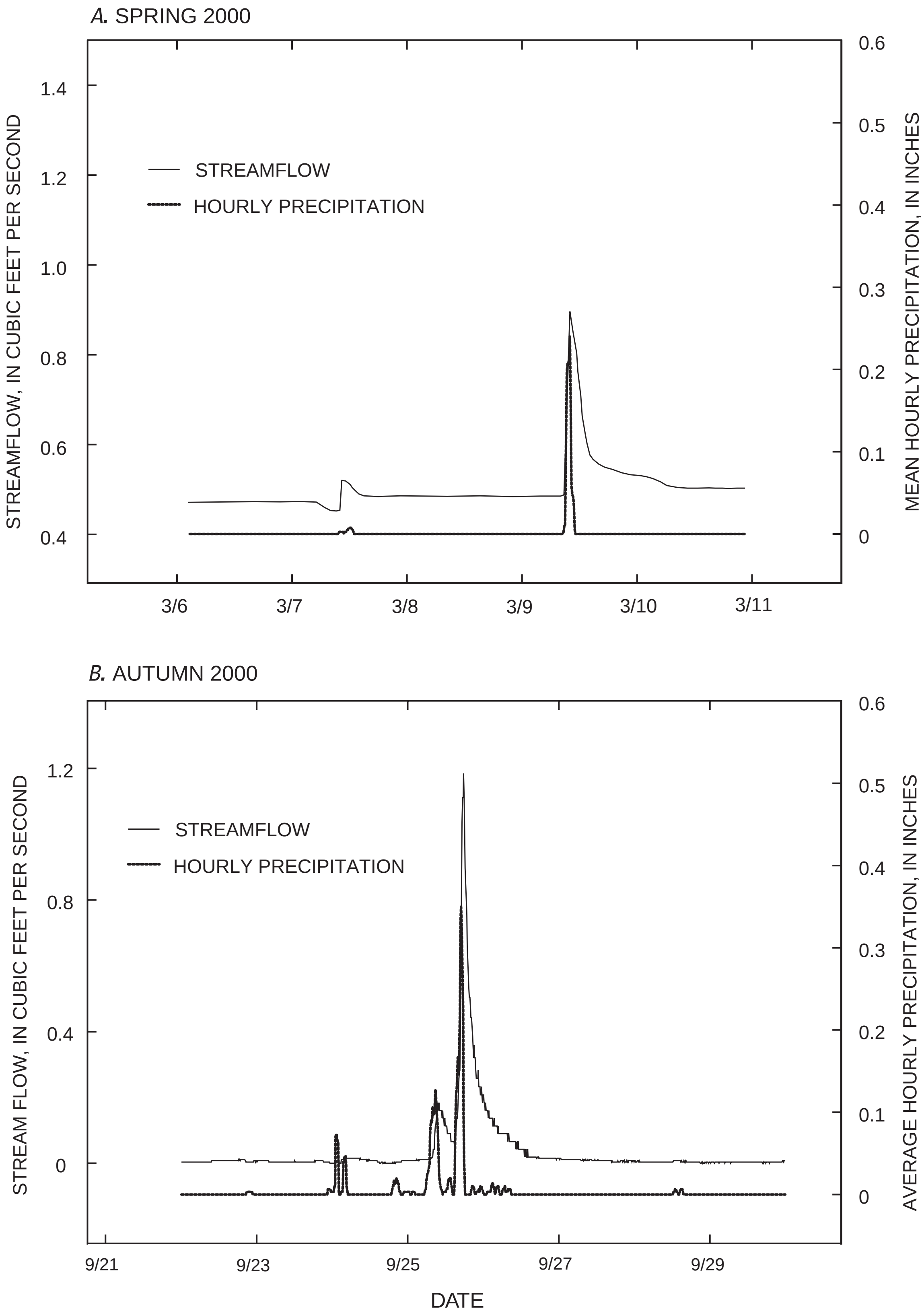

Figure 4. Streamflow and precipitation for the streamflow-gaging station (03204210) on a small stream near Mud, in the mountaintop coal-mining region of southern West Virginia during (*A*) a spring 2000 precipitation event, and (*B*) an autumn 2000 precipitation event.

apparent channel to the receiving stream at the mouth of the drainage area at an elevation of approximately 900 ft above sea level. A deep mine that dewaters some streams between approximately 900 and 1,200 ft above sea level, however, is suspected to be the cause of a lack of flow in that stream for most visits.

All collected data were put into spreadsheets, and all the intermittent- and perennial-point GPS locations were mapped digitally with ArcGIS 8.1 software. The coordinates of points were verified by comparison to digital orthophoto quarter-quadrangle maps and digital raster graphics (DRGs). Most GPS locations obtained in the field were accurate with respect to these datasets. Drainage areas of intermittent and perennial points were digitized at the 1:24,000 scale by use of the National Elevation Dataset (NED), which has a 30-meter horizontal accuracy (U.S. Geological Survey, 1999). Characteristics such as drainage area, elevation of origin point, mean drainage-area slope, aspect directions, and areal percentage of the dominant rock type were calculated for the drainage-area coverages on the basis of NED data, DRGs, and the digital geologic map of West Virginia (West Virginia Department of Environmental Protection, 1998). Mean drainage-area slope was calculated on the basis of the contour-band method of calculation (Horton, 1932; Eash, 1994); drainage-area slope can affect infiltration, surface runoff, soil moisture, and, possibly ground-water discharge to streams (Eash, 1994). A correlation analysis was used to assess the influence of the measured characteristics on intermittent- or perennial-point drainage area.

CHARACTERISTICS OF HEADWATER STREAMS

In the coal-mining region of southern West Virginia, intermittent points were identified for streams in 35 of 36 drainage areas, and perennial points were identified for streams in 20 of 36 drainage areas (fig. 1, table 2). There was no flow in 20 of the drainage areas included in this study in at least one spring or autumn site visit. Additionally, 23 intermittent points and 11 perennial points were visited 2 years in a row in order to give an indication of temporal variability of the origin of flow in response to climatic conditions.

Drainage Areas with Intermittent Flow

The highest elevation of the water table and the beginning of intermittent base flow (intermittent point) was identified for 35 headwater streams in February 2000 and March–April 2001 (table 2). For 27 sites visited in February 2000, the median drainage area was 15.9 acres; and for 31 sites visited in March or April 2001, the median drainage area was 17.9 acres. The smallest drainage area in either year upstream of an intermittent point was 6.3 acres, and the largest drainage area was 52.5 acres.

If a site was visited more than once, the intermittent point with the smaller drainage area was used in the balance of this analysis, because the current SMCRA and Clean Water Act issue under scrutiny is whether or not fill material can be placed in intermittent and perennial streams. The median drainage area of this subset of intermittent points (table 3) is 14.5 acres. The median basin slope of these drainage areas is 388 ft/mi. All following analyses are based on this subset of the data because not all of the sites were visited two times.

The median area for the 1,782 permitted valley fills in southern West Virginia is 12.0 acres (West Virginia Department of Environmental Protection, 2002), which is slightly smaller than the median intermittent-point drainage area (14.5 acres). The maximum size of a permitted fill (480 acres) is more than 10 times the observed maximum intermittent-point drainage area of 45.3 acres (table 3). Currently, some large fills cover more than one headwater drainage area.

In the northeastern part of the study area, mostly sandstone is exposed at the surface, intermittent-point elevations are higher (fig. 5A), and the average annual precipitation (approximately 47 in.) is generally greater. Intermittent points in the northeast had a median drainage area of 20.4 acres, and median basin slope of 322 ft/mi (table 3, figs. 5*B*, 5*C*). In the southwestern part of the study area, shale and sandstone are exposed at the surface, intermittent-point elevations are generally lower (fig. 5), and average annual precipitation (approximately 44 in.) is less. Intermittent points in the southwest had a median drainage area of 12.9 acres, and median basin slope of 465 ft/mi (table 3, figs. 5*B*, 5*C*).

Table 3. Selected drainage-area and hydrologic characteristics of intermittent points used in data analysis for headwater streams in the mountaintop coal-mining region of southern West Virginia, 2000–01

[**Sampling site:** See figure 1 for site locations and names. ***,** Data not collected in field season. ****,** Streamflow not measureable. ft, feet; ft/mi, feet per mile; ft^3/s, cubic feet per second; µS/cm; microsiemens per centimeter]

Sampling site	Region	Year	Drainage area, in acres	Intermittent point elevation, in ft	Basin slope, in ft/mi	Drainage area aspect	Dominant rock type	Percentage dominant rock type	Temperature, in °C	Streamflow, in ft^3/s	Conductance, in µS/cm
FF1	NE	2001	8.1	1,847	186	NW	sandstone	100	7	0.008	110
FF1a	NE	2001	18.3	1,493	338	SW	sandstone	100	11.5	.016	214
FF3	NE	2000	10.8	1,709	223	NW	sandstone	100	*	*	*
FF4	NE	2000	45.3	1,575	333	W-NW	sandstone	100	*	*	*
RNB	NE	2000	11.3	1,808	264	S	sandstone	100	*	*	*
RNC	NE	2000	40.6	1,595	416	SW	sandstone	100	*	*	*
RND	NE	2000	8.9	1,765	233	W-SW	sandstone	100	*	*	*
RNE	NE	2000	30.6	1,627	348	W	sandstone	100	*	*	*
RNF	NE	2000	19.4	1,732	275	N-NW	sandstone	100	*	*	*
RNG1	NE	2000	20.4	1,811	350	W-NW	sandstone	100	*	*	*
RNG2	NE	2001	28.0	1,791	322	W-SW	sandstone	100	7.5	**	27
RNG3	NE	2001	22.2	1,749	275	N-NW	sandstone	100	7.5	.021	36
RNH	NE	2001	40.7	1,601	433	NW	sandstone	100	8.5	.001	40
HC1a	SW	2000	12.0	1,076	393	SW	sandstone	100	*	*	*
HC1b	SW	2000	24.4	1,014	583	NW	sandstone	100	*	*	*
HC2	SW	2001	22.2	1,011	596	SW	sandstone	75	10	.018	283
HC3a	SW	2001	24.2	978	552	S-SW	sandstone	98	8	.032	534
HC3b	SW	2000	13.8	978	587	N-NW	sandstone	100	*	*	
HC4a	SW	2001	7.7	1,086	310	W-SW	sandstone	100	6.5	.022	616
HC4b	SW	2001	7.7	984	485	W-NW	sandstone	100	7	.002	349
HC5	SW	2000	9.6	971	488	W-NW	sandstone	100	*	*	*
HC6a	SW	2000	16.4	981	554	N	sandstone	91	*	*	*
HC6b	SW	2001	17.9	892	617	NE	sandstone	100	7.5	.008	55
LB1	SW	2001	10.8	1,053	380	W	shale	99	9	**	22
LB2	SW	2001	12.7	1,056	315	S-SW	shale	71	10.5	**	36
LB3	SW	2001	17.7	1,034	408	S-SE	sandstone	80	10	**	39
LB4	SW	2000	7.9	1,027	323	S-SE	sandstone	100	*	*	*
LB5	SW	2001	13.1	1,024	388	SE	sandstone	73	10	**	38
WF1a	SW	2000	14.5	1,096	343	S-SE	shale	67	*	*	*
WF1b	SW	2000	6.3	1,040	505	E-NE	shale	100	*	*	*
WF2a	SW	2001	10.7	899	513	N-NE	shale	51	9.5	.022	47
WF2b1	SW	2000	14.9	955	392	S-SE	sandstone	78	*	*	*
WF2b2	SW	2001	21.2	922	490	E	shale	92	7	.003	51
WF3a	SW	2001	7.9	1,011	365	N-NW	shale	99	5	.023	55
WF3b	SW	2000	10.9	1,001	444	NE	shale	100	*	*	*

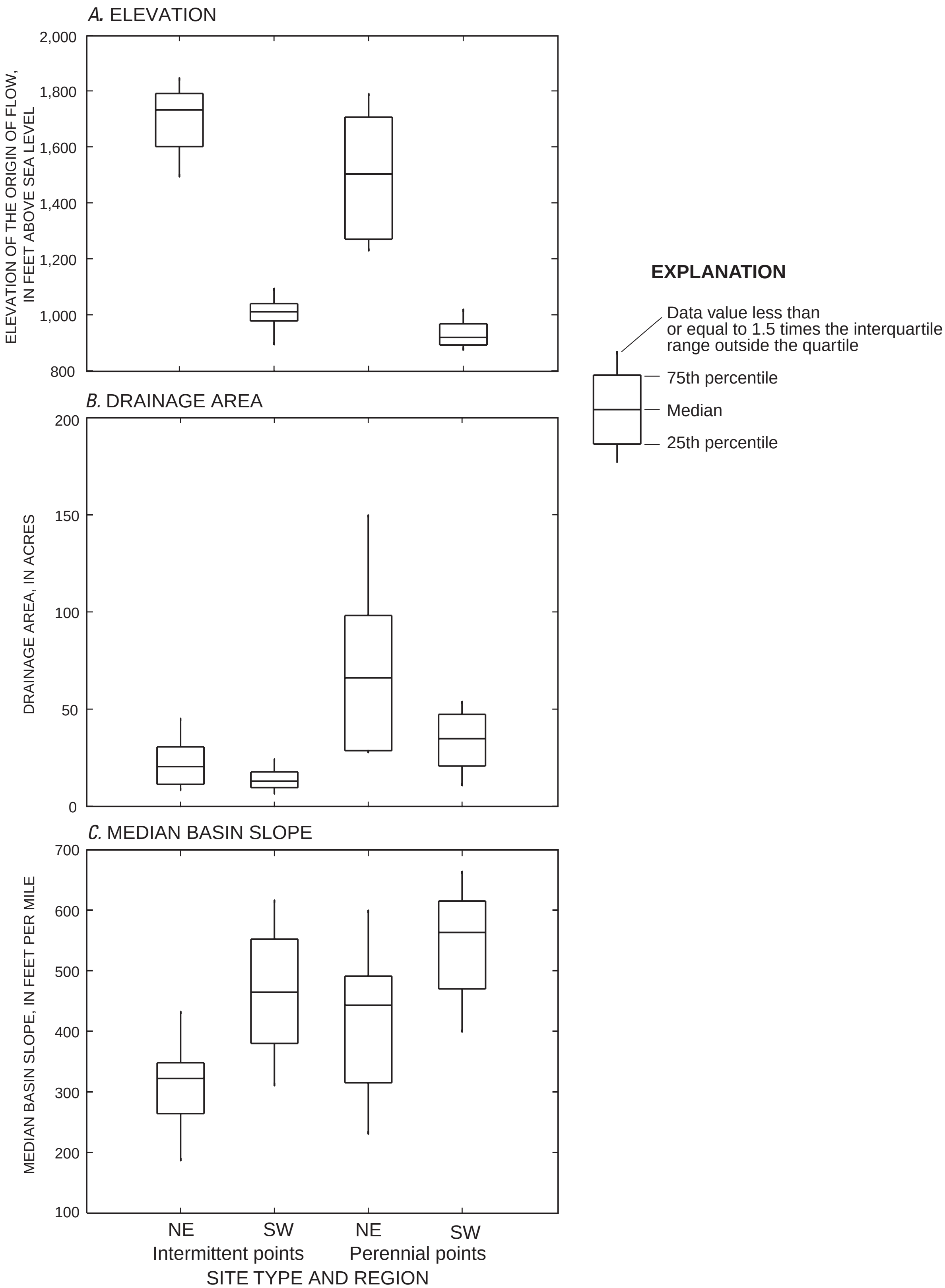

Figure 5. Distribution of (*A*) elevation, (*B*) drainage area, and (*C*) median basin slope for intermittent and perennial points in headwater streams of the mountaintop coal-mining region of southern West Virginia, 2000–01.

Intermittent-point drainage-area aspect, the general direction that water flows in a drainage area, varies from N to N-NW overall (table 3), and has a significant correlation with intermittent-point drainage area ($R = 0.23$, $p < 0.05$). Flow volume at intermittent points was small, with a median of 0.017 ft^3/s, and a range of 0.001 to 0.032 ft^3/s (table 3). Specific conductance ranged from 22 to 616 µS/cm, with a median of 51 µS/cm. Water temperature ranged from 5–11.5°C, with a median of 8.0°C.

Drainage Areas with Perennial Flow

The lowest elevation of the water table, and beginning of continuous perennial base flow (perennial point), was identified for 20 headwater streams in October of 2000 or October 2001 (table 2). For all October 2000 sites, the median drainage area was 41.4 acres, and for all October 2001 sites, the median drainage area was 28.5 acres. The 6-month period preceding the October 2000 visits to the perennial points was wetter than the period preceding the October 2001 visits (table 1).

If a site was visited in both years, the larger perennial-point drainage area between the two years was used in the statistical analysis (table 4); the stream above the lower perennial point is assumed to be intermittent. Also included are four sites that produced perennial flow in 2001, but not in 2000. The median drainage area upstream of this subset of perennial points was 40.8 acres. The minimum perennial-point drainage area was 10.4 acres, while the maximum drainage area was 150.1 acres. Drainage areas of perennial points had a greater range in size across the study area than did intermittent-point drainage areas; this result suggests that low base flow in the autumn may be more sensitive to local differences in climatic and drainage-basin conditions than high base flow in late winter and early spring. All of the following analyses are based on this subset of the data (table 4) because not all of the sites were visited two times.

Headwater streams had perennial base flow only where more than 80 percent of the bedrock exposed at the surface is sandstone, regardless of location within the study unit (table 4). Median elevation of perennial points (1,503 ft) was higher in the northeastern part of the study area (fig. 5*A*); the median drainage area was 66.1 acres and the median basin slope was 443 ft/mi (table 4, figs. 5*B*, 5*C*). Perennial points in the southwestern part of the study unit had a median elevation of 919 ft, a median drainage area of 34.8 acres, and a median basin slope of 563 ft/mi (table 4, fig. 5).

Drainage-area aspect for perennial points ranges from N to N-NW, with most basins facing SW, W-NW, and NW (table 4); drainage-area aspect was not significantly correlated to the drainage area of perennial points ($R = 0.36$, $p > 0.05$). Flow volume at perennial points varied little from site to site, with a range of 0.001 to 0.014 ft^3/s, and a median of 0.007 ft^3/s. Specific conductance varied from 32 to 721 µS/cm, with a median of 73 µS/cm. Water temperature ranged from 9.0 to 16.0°C, with a median of 12.8°C.

Of the 36 drainage areas evaluated during this study (table 2), six streams had no flow for only one visit and twelve streams were dry for both October visits. Half of these drainage areas contained at least 20 percent shale bedrock. Over half of the drainage areas were adjacent to at least one other drainage area with intermittent flow. Drainage-area aspect was evenly distributed in all directions. These observations suggest that local climatic and drainage basin conditions determine whether or not there will be perennial flow in a first-order headwater stream.

Temporal Variability in Intermittent and Perennial Drainage Areas

The point of flow origin for intermittent and perennial flow fluctuated over time, probably because of differences in environmental variables, including evapotranspiration, antecedent climatic conditions, and drainage basin conditions. This study quantified elevation, rock type, aspect, and basin slope for intermittent- and perennial-point drainage areas for two years at 23 and 11 sites, respectively.

The intermittent points were identified for 23 sites in both February 2000 and March–April 2001 (table 5). The intermittent-point drainage area varied by a median of 3.4 acres between these two periods overall. The regional pattern was evident in this analysis as well: northeastern intermittent-point drainage areas varied by a median of 7.0 acres, while southwestern drainage areas had a median variation of 1.9 acres. The drainage areas for intermittent points for February 2000 and March–April 2001 were significantly correlated by linear regression ($R = 0.87$, $p < 0.05$).

Table 4. Selected drainage-area and hydrologic characteristics of perennial points used in data analysis for headwater streams in the mountaintop coal-mining region of southern West Virginia, 2000–01

[**Sampling site:** See figure 1 for site locations and names. *****, Data not collected in the October 2000 field season. ft, feet; ft/mi, feet per mile; ft^3/s, cubic feet per second; µS/cm; microsiemens per centimeter]

Sampling site	Region	Year	Drainage area, in acres	Perennial point elevation, in ft	Basin slope, in ft/mi	Drainage area aspect	Dominant rock type	Percentage dominant rock type	Temperature, in °C	Streamflow, in ft^3/s	Conductance, in µS/cm
FF3	NE	2001	122.3	1,244	539	NW	sandstone	100	14	<0.003	90
FF4	NE	2001	98.2	1,457	443	W-NW	sandstone	100	14	<.003	121
RNC	NE	2001	66.5	1,503	491	SW	sandstone	100	11	<.003	32
RNE	NE	2001	66.1	1,227	480	W	sandstone	100	12	<.002	44
RNF	NE	2000	41.9	1,618	315	N	sandstone	100	13	.011	43
RNG1	NE	2000	27.6	1,759	347	W-NW	sandstone	100	12.5	.014	*
RNG2	NE	2001	28.4	1,791	230	W-SW	sandstone	100	9	<.002	155
RNG3	NE	2001	28.6	1,706	301	N-NW	sandstone	100	11.5	<.002	47
RNH	NE	2001	150.1	1,270	600	NW	sandstone	100	11	<.003	90
HC1a	SW	2000	54.0	915	541	SW	sandstone	100	12.5	<.005	73
HC1b	SW	2000	40.7	945	596	NW	sandstone	100	12	<.010	61
HC2	SW	2000	47.3	919	664	SW	sandstone	82	13	.001	234
HC3a	SW	2001	24.1	978	554	SW	sandstone	98	16	<.003	360
HC3b	SW	2000	40.8	902	615	NW	sandstone	100	13	.003	195
HC4	SW	2001	23.0	879	589	W	sandstone	100	14	.002	600
HC4a	SW	2000	10.4	1,020	398	W	sandstone	100	13	.012	721
HC6a	SW	2001	20.7	873	563	N	sandstone	93	16	<.005	67
HC6b	SW	2001	18.0	892	620	NE	sandstone	100	14	<.003	73
LB3	SW	2000	52.0	958	470	S-SE	sandstone	88	11.8	<.003	62
LB5	SW	2001	34.8	968	453	SE	sandstone	89	12.5	<.003	38

Regional late winter to early spring precipitation patterns can create small, local differences in the drainage areas of intermittent points, but there was no clear direction to the differences, regardless of location in the study area. The period (October–March) preceding the 2000 field work was slightly wetter than the period preceding the 2001 field work (Ward and others, 2001, 2002) (table 1), but only 57 percent (13 of 23) of intermittent-point drainage areas were larger in 2001 than in 2000. Overall, October through March of both 2000 and 2001 were significantly drier than normal, which may have had a cumulative affect on the drainage areas of the intermittent points. There is a significant relation between drainage areas for intermittent points in March–April 2001 and perennial points in October 2000 ($R = 0.97$, $p < 0.05$).

The perennial points were identified for 11 sites in both October 2000 and October 2001. The drainage areas upstream of these perennial points varied by a median of 18.0 acres between 2000 and 2001 (table 5). The variation in drainage areas over time was much larger for perennial points (18.0 acres) than for intermittent points (3.4 acres), overall. Precipitation in the summer and early autumn in this region is delivered primarily by local convection thunderstorms, which can cause wide variability in water-table elevations across the region. Drainage areas of perennial points in October of 2001 were significantly correlated to drainage areas of perennial points in October 2000 ($R = 0.86$, $p < 0.05$).

There was a difference in the medians of the temporal variation in drainage areas for perennial points in the northern and southwestern regions. The median of the variation for the northeastern basins was 22.2 acres, and 11.7 acres for the southwestern basins. Perennial point drainage areas where the rock type is sandstone, which are distributed across the study area, varied by a median of 20.1 acres. Drainage areas with as much as

Table 5. Differences in drainage area between intermittent and perennial points in 2000 and 2001 for headwater streams in the mountaintop coal-mining region of southern West Virginia

[**Sampling site:** See figure 1 for site locations and names. **Dominant rock type:** The rock type listed represents greater than 50 percent of the surface geology. **Difference:** 2000 value minus 2001 value. ***,** Intermittent or perennial point not visited in both years.]

Sampling site	Region	Dominant rock type	Intermittent-point drainage areas, in acres			Perennial-point drainage area, in acres		
			2000	2001	Difference	2000	2001	Difference
FF1	NE	sandstone	19.4	8.1	11.3	*	*	*
FF3	NE	sandstone	10.8	19.0	-8.2	65.0	122.3	-57.3
FF4	NE	sandstone	45.3	52.5	-7.2	*	*	*
RNC	NE	sandstone	*	*	*	44.2	66.5	-22.2
RND	NE	sandstone	8.9	13.3	-4.4	*	*	*
RNE	NE	sandstone	30.6	43.2	-12.6	*	*	*
RNF	NE	sandstone	19.4	23.2	-3.8	*	*	*
RNG1	NE	sandstone	20.4	27.5	-7.0	27.6	27.5	0.2
RNG2	NE	sandstone	31.4	28.0	3.4	*	*	*
RNG3	NE	sandstone	22.2	22.2	.0	22.2	28.6	-6.4
RNH	NE	sandstone	*	*	*	125.9	150.1	-24.2
HC1a	SW	sandstone	12.0	15.0	-3.0	54.0	28.5	25.5
HC1b	SW	sandstone	24.4	31.8	-7.5	40.7	35.3	5.4
HC2	SW	sandstone	26.5	22.2	4.3	47.3	19.7	27.6
HC3a	SW	sandstone	*	*	*	23.4	24.1	-.7
HC3b	SW	sandstone	*	*	*	40.8	22.8	18.0
HC4a	SW	sandstone	8.4	7.7	.6	*	*	*
HC4b	SW	sandstone	9.2	7.7	1.5	*	*	*
HC6a	SW	sandstone	16.4	19.7	-3.3	*	*	*
HC6b	SW	sandstone	18.0	17.9	.1	*	*	*
LB4	SW	sandstone	7.9	10.1	-2.2	*	*	*
LB5	SW	sandstone	*	*	*	34.0	34.8	-.8
WF1a	SW	shale	14.5	24.7	-10.2	*	*	*
WF1b	SW	shale	6.3	10.1	-3.8	*	*	*
WF2a	SW	shale	10.7	10.7	.0	*	*	*
WF2b1	SW	sandstone	15.9	14.9	1.0	*	*	*
WF2b2	SW	shale	22.2	21.2	1.1	*	*	*
WF3b	SW	shale	10.9	12.1	-1.2	*	*	*

18 percent shale are in only the southwestern part of the study area, and had a median variation between years of only 0.8 acre.

Although the period (April–September) preceding October 2000 field work was wetter than the period preceding October 2001 field work, 36 percent (4 of 11) of perennial points had larger drainage areas in 2001, 36 percent (4 of 11) were larger in 2000, and 27 percent (3 of 11) varied less than one acre. Six perennial points not included in the statistical comparison of 11 sites did contain flow in 2001, but not in 2000 (table 2). As noted earlier, only drainage areas composed of mostly sandstone produced perennial flow.

The uncertainty in these results associated with GPS and mapping methods employed in this study is unknown, but the magnitude and significance of regression relations identified above suggest that the patterns identified here are robust for this small dataset. Variations in drainage-area size upstream of intermittent and perennial points over time probably are affected by antecedent climatic conditions and drainage basin conditions. However, the local conditions for small headwater basins are extremely variable, and relations of these conditions to intermittent and perennial points could not be defined with this limited study.

SUMMARY AND CONCLUSIONS

Characteristics of first-order perennial, intermittent, and ephemeral headwater streams in the mountaintop coal-mining region of southern West Virginia were measured and quantified in the late winter or early spring and autumn of 2000 and 2001. The origins of flow in headwater streams previously had not been examined in West Virginia, but are important to know because of the 1999 and 2002 U.S. District court rulings allowing the placement of valley-fill material only in ephemeral streams and not within 100 feet of intermittent and perennial streams.

The point of continuous base flow in a stream, after no recent precipitation, can be identified and mapped as the surface expression of the water table. The time of year of field work is an important factor in this approach. Many streams throughout West Virginia have their lowest base flows in late summer or early autumn, and their highest base flows in late winter or early spring. The point where base flow begins in the late winter or early spring corresponds to the highest water-table elevation, and is the point of intermittent-flow origin (intermittent point). The point where base flow begins in the late summer or early autumn corresponds to the lowest water-table elevation, and is the point of perennial-flow origin (perennial point).

The study area included 43 sites around the southern coal fields of West Virginia. Because previous coal mining affected 7 sites, only 36 sites were used in this study. For both intermittent and perennial streams in both years, flow at the point of origin was generally less than 0.01 ft^3/s. Specific conductance varied from 22–616 µS/cm for all sites and for all field seasons, and was not a good indicator of past mining history. Water temperature ranged from 5.0 to 11.5°C in the late winter or early spring, and from 9.0 to 16°C in the autumn.

The median drainage area upstream of 34 intermittent points was 14.5 acres, and ranged from 6.3 to 45.3 acres. The median size of permitted valley fills in southern West Virginia is 12.0 acres, which is comparable to the median area upstream of the intermittent point (14.5 acres). The maximum size of permitted fills (480 acres) is more than 10 times the observed maximum intermittent-point drainage area (45.3 acres). The intermittent points in the northeastern part of the study unit were underlain by sandstone bedrock, were higher in elevation, had higher antecedent precipitation totals, and had larger median drainage areas (20.4 acres) and less steep median basin slopes (322 ft/mi) than the southwestern intermittent points (12.9 acres; 465 ft/mi, respectively).

The median drainage area for 20 perennial points was 40.8 acres, and ranged from 10.4 to 150.1 acres. Perennial-point basins in the northeastern part of the study unit had a median elevation of 1,503 ft, a median drainage area of 66.1 acres and a median basin slope of 443 ft/mi. Perennial points in the southwestern part of the study unit had a median elevation of 919 ft, a median drainage area of 34.8 acres, and a median basin slope of 563 ft/mi. Only drainage areas underlain by sandstone bedrock produced perennial flow, regardless of geographic location.

Intermittent-point drainage areas varied over time by a median of 3.4 acres between two annual late-winter or early spring measurements for 23 sites. There was a regional pattern in this dataset: northeastern drainage areas for intermittent points varied by a median of 7.0 acres, while southwestern drainage areas for intermittent points varied by a median of 1.9 acres. The results indicate that local antecedent climatic conditions and drainage basin conditions control the location of the intermittent point.

Perennial-point drainage areas varied over time by a median of 18.0 acres between two annual autumn measurements for 11 sites. Perennial points in northeastern drainages varied over time by a median of 22.2 acres, whereas those in the southwestern drainages varied over time by a median of 11.7 acres. This could be partially explained by rock types, as shale was present only in the southwestern drainage areas; only drainage areas composed of mostly sandstone produced perennial flow. The October 2001 perennial-point drainage area was significantly correlated to the perennial-point drainage area of October 2000 ($R = 0.86$, $p < 0.05$). Twenty streams had no flow for one or two annual October visits. These drainage areas were adjacent to similarly sized drainage areas that did produce perennial flow. These factors suggest that perennial flow in a stream is controlled by very local climatic and drainage basin conditions at a first-order stream scale.

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A Survey of Eight Major Aquatic Insect Orders Associated with Small Headwater Streams Subject to Valley Fills from Mountaintop Mining

INTRODUCTION

In the study area many small ephemeral, intermittent, and permanent streams are subject to burial as a result of mountaintop removal/valley fill (MTR/VF) activities. There has been little or no assessment as to what biota and habitats are being affected. Studies in other regions suggest that many intermittent and temporary streams may contain a diverse assemblage of species and aquatic biota. For example, in western Oregon taxa richness of invertebrates (> 125 species) in temporary streams exceeded that of 100 species found in a permanent headwater (Dieterich and Anderson 2000). In several northern Alabama streams, Feminella (1996) could find little difference between the number of invertebrate taxa found in permanent streams versus those found in intermittent stream reaches. In contrast, some studies have found taxonomic diversity to be depressed in intermittent headwater streams compared to permanent downstream reaches (Brussock and Brown 1991).

Dieterich and Anderson (2000) found 13 previously undescribed taxa of invertebrates associated with the temporary headwater stream. Morse et al. (1993, 1997) have pointed out that many small spring brooks and spring seeps in the Appalachian region harbor a diverse and unique array of invertebrates. Furthermore, a number of the unique species are known from only one or two isolated locations in the Appalachians (Morse et al. 1993, 1997). However, other than the knowledge that small spring brooks and spring seeps may contain unique species in the Appalachians, we know little about benthic community structure and distribution in intermittent streams within the coalfield area. In order to assess community structure in these small headwater streams potentially subject to burial, a survey was undertaken during the late winter and early spring of 2000 to assess biotic inventories in several intermittent and permanent headwater stream systems.

The purpose of the survey was to assess the potential limits of viable aquatic communities based on biological criteria, which may be useful in delineating stream buffer zones as they relate to valley fills created by MTR/VF practices. Specifically, several questions were addressed by the exercise: What are the upper limits of distribution of aquatic insects belonging to the orders Ephemeroptera, Odonata, Plecoptera, Megaloptera, Trichoptera, Coleoptera, and Diptera within the intermittent and permanent headwater reaches? What is the distribution of various functional groups of aquatic insects, i.e., shredders, collectors, gatherers, and predators in these headwater streams? How does invertebrate community structure and taxa diversity vary with distance from the headwaters and watershed area? What is the relative distribution of taxa with regard to length of aquatic life required to complete development, i.e., are only those taxa with shorter (<9 months) life cycles found in the intermittent headwater reaches? To assess these questions streams were studied in southern West Virginia and eastern Kentucky, where all or parts of the streams are scheduled for burial by MTR/VF mining. It should be emphasized that most of the streams included in this inventory do not appear on USGS 1:24000 maps and, in fact, many do not even appear as a dashed blue line indicating the existence of an intermittent stream on existing USGS maps.

METHODS

Field methods

Five proposed surface mining sites in West Virginia and one site in Kentucky were selected for study. Each site had three or more headwater streams planned for valley fills. A total of 36 streams and spring seeps were sampled in West Virginia and Kentucky. Three of the 36 are reference streams. All streams and spring seeps were sampled between February 15 and April 15, 2000.

Two field teams, four to five members, were organized to conduct the stream surveys. Each team had a professional biologist with experience in aquatic macroinvertebrate taxonomy, and one person with experience using global positioning systems (GPS).

The first sampling point for each headwater stream was located in the field, where the contiguous surface flow began. Other sampling locations were located 50, 150, 350, and 550 meters downstream of the point of contiguous flow using a 100-meter tape. If needed, additional points were sampled at 400-meter intervals downstream until the mouth of the stream was reached, or a perennial stream as designated by a solid blue line on a USGS topographic map was encountered. Each sampling point was located on a USGS 7.5' topographic map and the GPS location recorded. Location information was recorded into a geographic information system and used to calculate watershed area, elevation and aspect at each sampling point. Again, many of these headwater streams are not shown as either intermittent or perennial streams on USGS 1:24000 maps.

At each sampling location, only aquatic insects in the orders Plecoptera, Ephemeroptera, Odonata, Megaloptera, Lepidoptera, Trichoptera, Coleoptera and Diptera were collected. Aquatic stages were taken with a D-frame net and hand picked with forceps from rocks and leaf-packs by three or four team members for ten minutes. The specimens were counted and identified to the family or genus level, and then preserved in ethyl alcohol for laboratory verification of counts and field identifications.

Data collected

The following information was gathered for each sampling point: site ID and station number; downstream distance from point of contiguous flow; area of watershed, elevation, stream aspect (compass orientation), number of individuals collected for each taxa, total number of taxa collected (richness), number of multi-year taxa (taxa which require >1 year for development in the aquatic juvenile stage), number of EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa, proportion of collectors, shredders, scrapers, and predators in the population. Multi-year life cycle data were obtained from Brigham et al. (1982) and Wallace and Anderson (1996). Functional group classification followed that presented in Merritt and Cummins (1996). For the proportion of functional groups at a given station, any station with $\leq$2 individuals was eliminated prior to analysis because they did not constitute a community.

RESULTS

Total individuals, orders, families, and genera

All 8 of the target orders of insects were found within the intermittent headwater reaches and within these orders there were 41 families and 73+ genera, the actual number of genera would far surpass 73 as chironomids were not identified to genus (Table 1). A total of 6,923 individuals were collected and identified from the study streams. Functionally, predators (24 taxa) dominated the total number of taxa collected followed by collectors (19 taxa), shredders (18 taxa), scrapers (5 taxa), and several facultative collector-scraper taxa based on the classification scheme of Merritt and Cummins (1996). Many of the genera listed in Table 1 are represented by more than one species in the study area. For example, a list of Plecoptera (stonefly) genera found in small headwater streams and spring seeps in eastern North America (Table 2) shows that over half of those genera listed are represented by multiple species. Additionally, the study area has not been adequately inventoried and a few species are known from only a few isolated localities.

Taxa richness and EPT richness

Taxa richness (number of taxa at a given site) increased (P<0.01, regression analyses) with increasing watershed area (Figure 1). The number of taxa increased rapidly up to a drainage area of about 150 to 200 acres and then tapered off with increasing watershed area. Many watersheds of less than 50 acres had 10 or more taxa.

The total number of EPT taxa (number of taxa belonging to the insect orders Ephemeroptera, Plecoptera, and Trichoptera and generally considered obligate aquatic insects indicative of good water quality) followed similar trends as taxa richness (Figure 2). In fact, the number of EPT taxa increased rapidly up to a watershed area of about 100 acres after which the rate of increase tapered off with increasing watershed area (Figure 2, P<0.01, regression analyses). As noted for taxa richness some extremely small spring seeps at the point of contiguous flow had multiple EPT taxa (Figure 2).

Functional differences in fauna along headwater gradients

The proportion of shredder taxa declined with increasing watershed area (P<0.01, regression analyses, Figure 3). In many of the smaller headwater drainages of less than 50 acres over half of the fauna collected were shredders. Collector taxa showed an opposite trend than that of shredder taxa. The proportion of collector taxa increased with increasing watershed area (P<0.01, regression analyses), with the rate of increase slowing once a watershed area of about 100 acres is reached (Figure 4). The proportion of samples composed of scraper taxa followed a similar, although weaker but significant (P<0.05), trend as that of collectors with increasing proportions as watershed area increased (Figure 5). In contrast to the other functional groups, the percent predators showed no trend with increasing watershed area or distance downstream (r^2 = 0.0085, Figure 6).

Table 1. Insect order, number of families and genera within each order found during survey of streams potentially subject to valley fills within the study areas.

Order	Number of families	Number of Genera
Ephemeroptera (mayflies)	4	8
Odonata (dragonflies & damselflies)	3	4
Plecoptera (stoneflies)	9	21
Megaloptera (alderflies, dobsonflies)	2	3
Coleoptera (beetles)	5	5
Trichoptera (caddisflies)	8	12
Lepidoptera (moths)	1	1
Diptera (true flies)	9	19[a]
Total =	41	73+

[a] = does not include Chironomidae genera

Table 2. Plecoptera (stoneflies) from eastern North America found only in first and second order streams, including seeps and springs (list compiled by R. F. Kirchner [U.S. Army Corps of Engr.] and B. C. Kondratieff [Colorado State University]). Note – ca. 50% of these species have been described as new to science in the last 25-30 years.

Family	**Genus**	**Number of known species**
CAPNIIDAE	*Allocapnia*	5
	Paracapnia	1
LEUCTRIDAE	*Leuctra*	6
	Paraleuctra	1
	Megaleuctra	2
NEMOURIDAE	*Nemoura*	1
	Ostrocerca	4
	Paranemoura	2
	Prostoia	1
	Soyedina	5
	Zapada	2
TAENIOPTERYGIDAE	*Taeniopteryx*	1
CHLOROPERLIDAE	*Alloperla*	2
	Rasvena	1
	Sweltsa	4
PELTOPERLIDAE	*Peltoperla*	2
	Tallaperla	5
	Viehoperla	1
PERLIDAE	*Beloneuria*	2
	Hansonoperla	2
PERLODIDAE	*Isoperla*	4
	Malirekus	2
	Oconoperla	1
	Yugus	3

Total number of individuals collected and life history

The total number of individuals collected at various sites increased with watershed areas (*P*<0.01, regression analyses, Figure 7). Overall the number of taxa collected increased rapidly from watershed areas of <10 to 100 acres and the rate of increase began to slow after watershed drainage areas approached 100 acres. The number of taxa with multi-year life cycles, i.e., requiring more than one year in the aquatic stage to complete their development, tended to increase in a downstream direction (Figure 8). Insects with multi-year life cycles were encountered in watersheds as small as 10 acres. However, even 100-acre watersheds had as many as 4 taxa with multi-year life cycles. Some of the multi-year taxa include the following: Plecoptera (stoneflies): *Peltoperla, Tallaperla, Eccoptura,* and *Acroneuria;* Odonata (dragonflies): *Lanthus*, *Cordulegaster*, and *Stylogomphus*; Megaloptera (fishflies): *Nigronia*. Coleoptera (beetles): *Anchytarsus.*

CONCLUSIONS

Most of these sites would not be considered streams based on existing USGS 1:24000 topographic maps. Furthermore, a number of taxa that are found in these extreme headwaters have multi-year life cycles suggesting that sufficient water is present for long-lived taxa to complete their juvenile development prior to reaching the aerial adult stage. The predominance of shredder taxa in the headwaters (Figure 3) suggests that the community structure in the extreme headwaters resemble those hypothesized by the river continuum concept for first order streams (Vannote et al. 1980). These streams all drained forested regions and leaf material from the surrounding forest was by far the most evident energy source (e.g. Wallace et al., 1997) as many streams were "choked" with leaves during the February to April sampling period. Much more work is needed on organic matter dynamics, e.g., input and output budgets, etc. in these small headwater streams of the central Appalachians. Furthermore, trend of increasing fine organic particle collectors downstream (Figure 4) suggests a system that is dependent on linkages upstream resources and surrounding forest. It is assumed that export to downstream areas is linked to both hydrologic events and animal activity (e.g. shredders processing leaf material to FPOM, which is more easily exported to downstream reaches).

Although only contiguous flow areas were considered in this study, the sampling was conducted following groundwater recharge from a major drought the preceding year. Presumably, these extreme headwaters are subject to annual surface drying. Benthic invertebrates exploiting temporary stream habitats have been separated into three groups of taxa: 1) those found primarily in permanent waters and displaying no specialized adaptations to life in intermittent waters; 2) generalist taxa that are facultative stream/pond generalist; and, 3) specialist species with specialized life cycles or adaptations for withstanding adverse periods of drying (Williams and Hynes 1977). For example, some invertebrates survive drought periods by migrating into the subsurface sediments known as the hyporheic zone (e.g., Clinton et al. 1996), whereas others may survive drought periods in intermittent pools, etc. (e.g. Smith and Pearson 1987), or have drought resistant stages or adaptations (Williams and Hynes 1977). However, to our knowledge none of the taxa identified above as having multi-year life cycles have any obvious specialized adaptations for surviving droughts, which suggests migration into hyporheic zones or intermittent pools during severe droughts. A number of workers have found remarkable similarity between fauna in temporary stream habitats with that found in nearby permanent streams (Feminella 1996, Delucchi 1989, Boulton and Lake 1992), whereas other have noted rather distinct differences among permanent and temporary forest streams (Dieterich and Anderson 2000).

Biodiversity

There are many species of aquatic vertebrates and invertebrates that are unique to headwater streams and spring seeps (Morse et al. 1993, 1997). For example, several species of aquatic insects that have been described (new to science) from first and second order streams in recent years from Kentucky, Virginia and West Virginia, include: *Hansonoperla hokolesqua, Allocapnia frumi, A. harperi, Alloperla aracoma, Peltoperla tarteri, Sweltsa pocahontas, Ameletus tarteri* and *Madeophylax* A list of Plecoptera (stoneflies) and number of species restricted to first and second order streams of eastern North America is presented in Table 2. It is important to emphasize that about 50% of the number of stonefly species listed in Table 2 have been described only within the last 25 to 30 years and new species are still being described from the region. Some of the taxa collected during this study restricted to small headwater streams, for instance: *Ostrocerca*, *Soyedina,* and *Peltoperla* (Plecoptera), *Diplectrona metaqui* Ross (a new WV state record), and *Homoplectra* (Trichoptera). For example, the larvae of *Homoplectra* now known occur in intermittent spring seeps in the headwaters of mountain stream (Huryn 1989). Thus, the view that there are so many small streams and springbrooks in the Appalachians that destroying a small portion represents a minor threat to biodiversity appears to be incorrect.

Very few taxonomic studies to the species level of identification (generally requiring the short-lived aerial adult stage) have been made in the small intermittent and permanent streams of the central Appalachians (see also Morse et al. 1993, 1997). This includes streams of the Kentucky, Tennessee, Virginia, and West Virginia coalfields. Thus, without adequate assessment by trained taxonomists, we do know how many species are present, their distribution, their current population status, or whether they are endangered or threatened with extinction. Hence, we are burying some potentially valuable and unique habitats without knowing the consequences of our actions. Investigations into the taxonomy, ecology, and distribution of species associated with headwater streams and spring seeps in MTR/VF areas should proceed with haste in order to document biotic inventories of the coalfield areas before many species are potentially lost forever without realizing their presence.

As others have pointed out, invertebrates inhabiting temporary streams can have high diversity and faunal similarity with permanent streams, therefore they should be considered in conservation plans designed to protect species and their habitats (Williams 1996, Feminella 1996).

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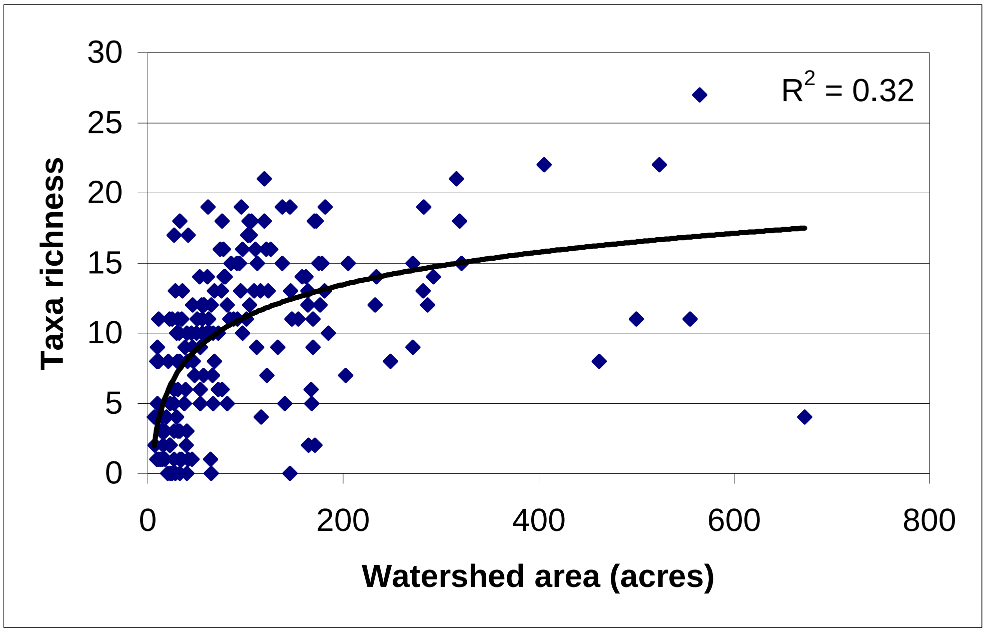


Figure 1. Number of different benthic macroinvertebrate taxa (richness) collected in each sample versus watershed drainage area at each sample location. Trendline fitted using the least squares method and a logarithmic function. The relationship is significantly different than zero ($p<0.01$).

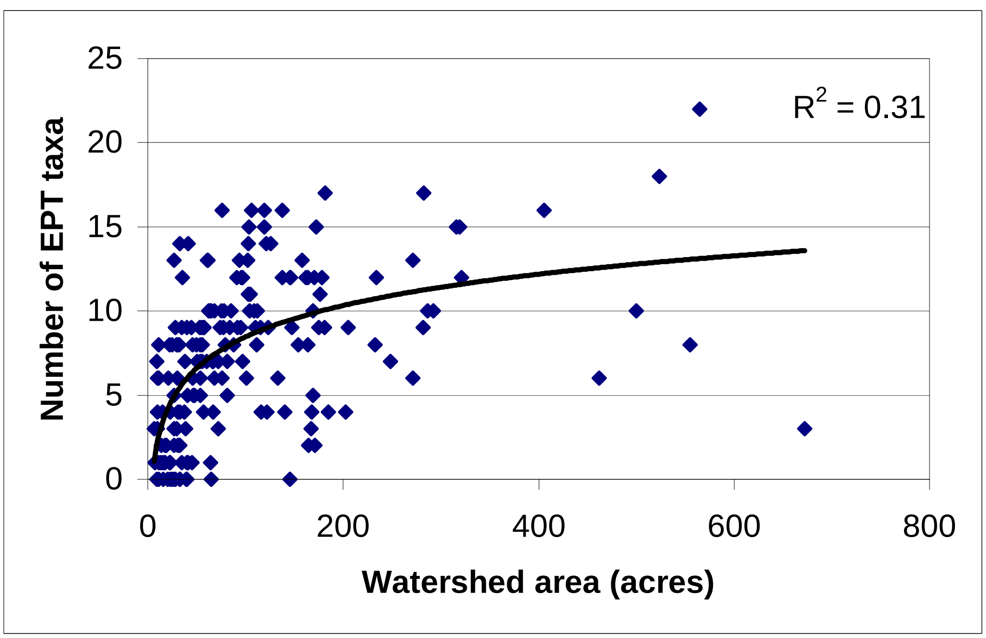


Figure 2. Number of EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa collected in each sample versus watershed drainage area at each sample location. Trendline fitted using the least squares method and a logarithmic function. The relationship is significantly different than zero ($p<0.01$).

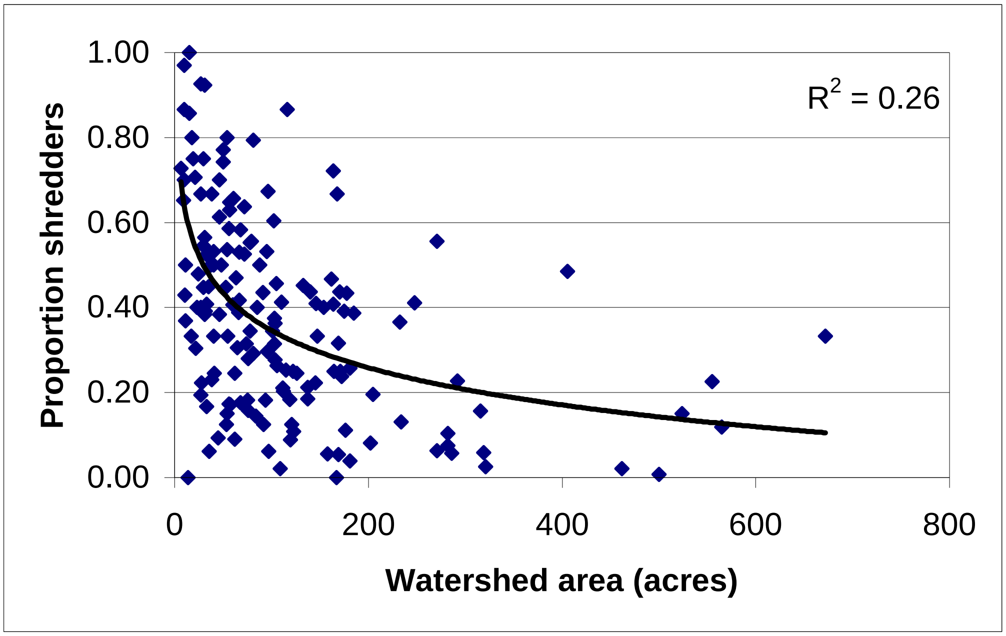


Figure 3. Proportion of benthic macroinvertebrate populations that function as leaf shredders collected in each sample, versus watershed drainage area at each sample location. Trendline fitted using the least squares method and a logarithmic function. The relationship is significantly different than zero ($p<0.01$).

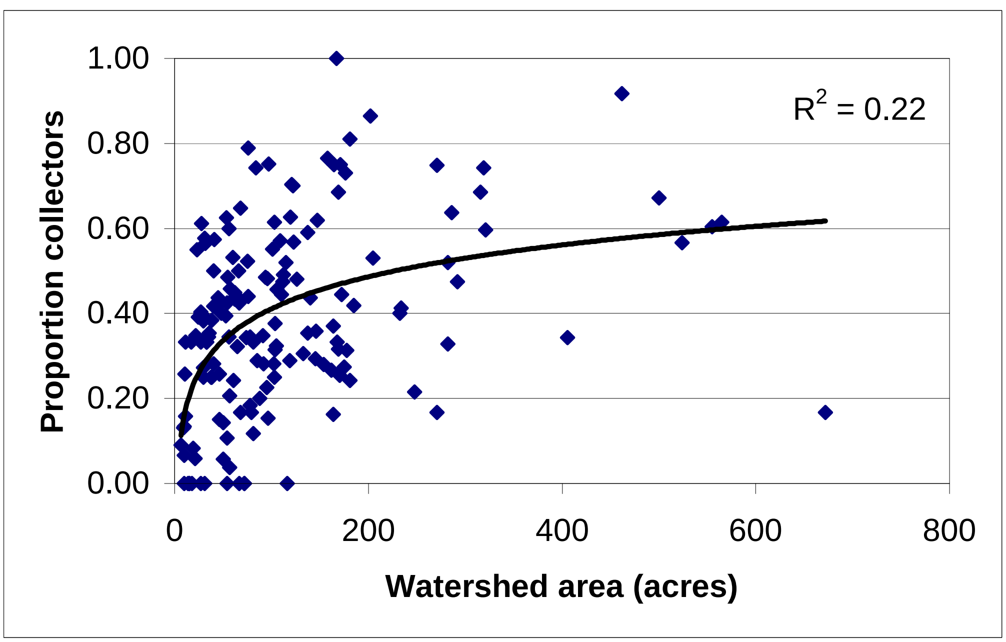


Figure 4. Proportion of benthic macroinvertebrate populations that function as fine particle collectors in each sample, versus watershed drainage area at each sample location. Trendline fitted using the least squares method and a logarithmic function. The relationship is significantly different than zero ($p<0.01$).

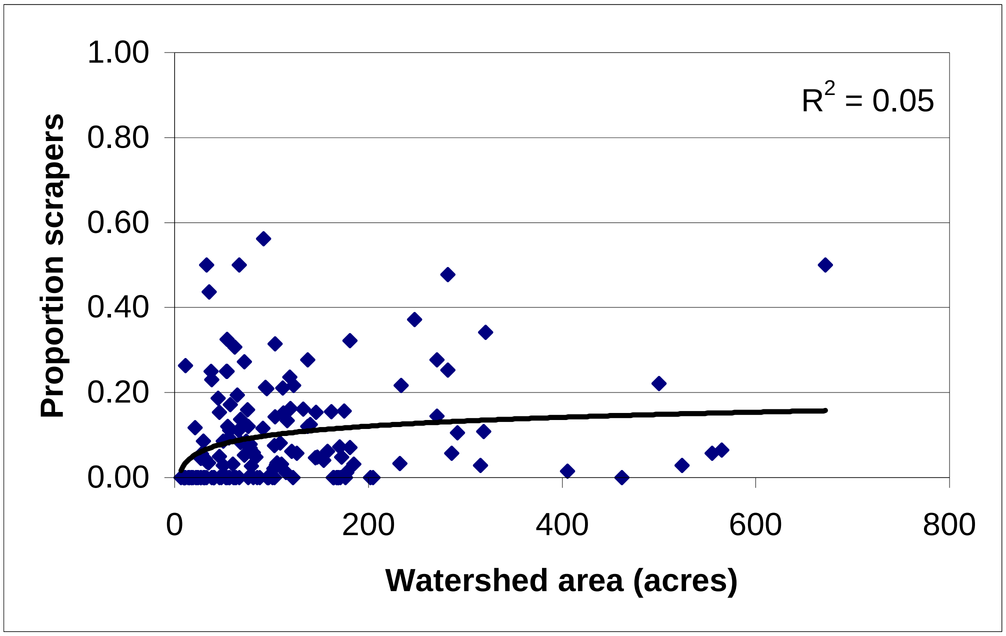


Figure 5. Proportion of benthic macroinvertebrate populations that function as biofilm (algae, bacteria, fungus) scrapers in each sample, versus watershed drainage area at each sample location. Trendline fitted using the least squares method and a logarithmic function.

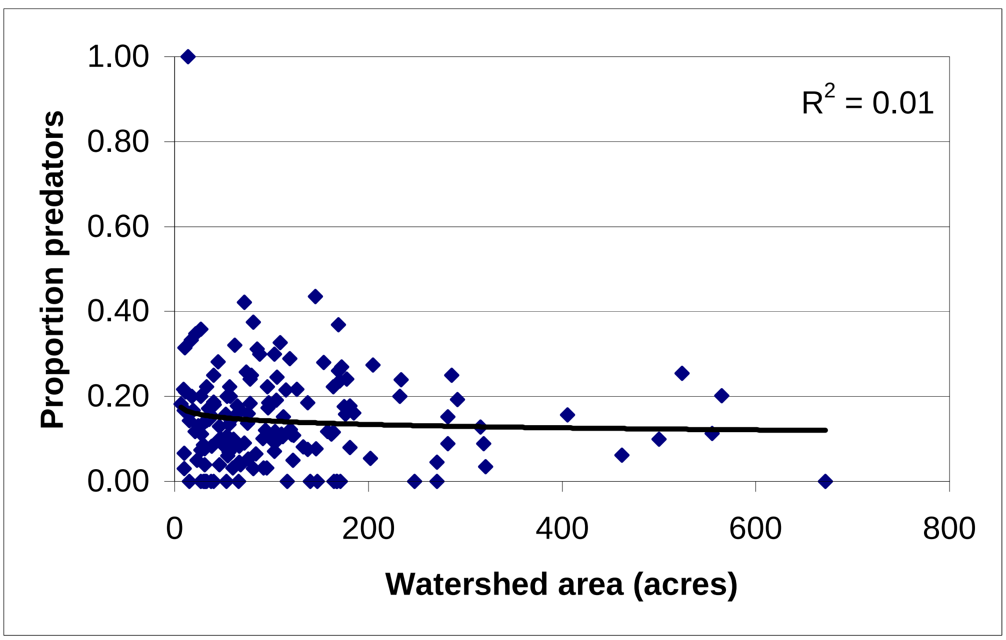


Figure 6. Proportion of benthic macroinvertebrate populations that function as predators in each sample, versus watershed drainage area at each sample location. Trendline fitted using the least squares method and a logarithmic function. The relationship is not significantly different than zero (p>0.01).

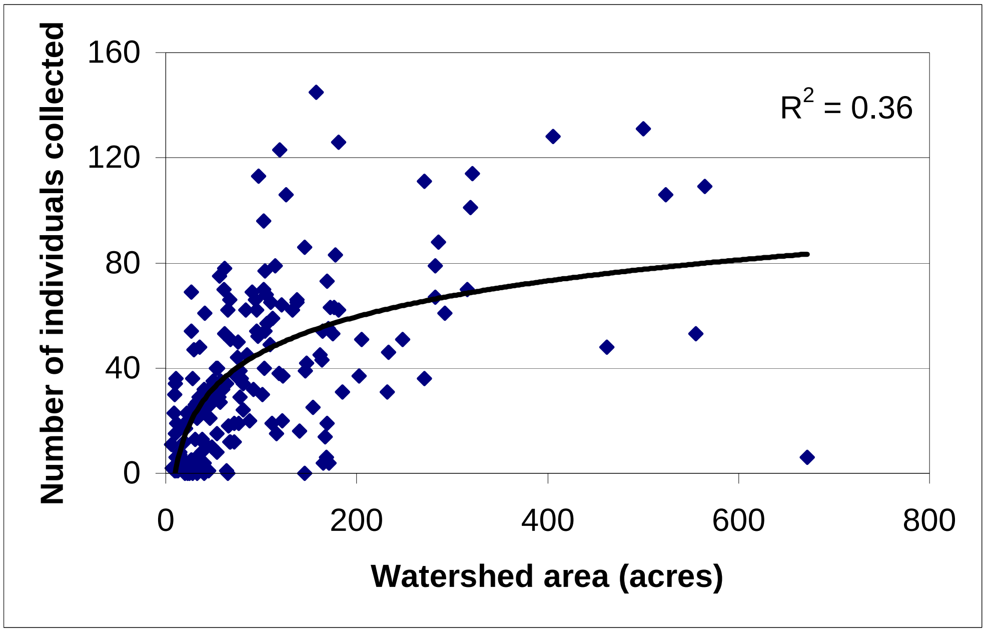


Figure 7. Total number of benthic macroinvertebrates collected in each sample versus watershed drainage area at each sample location. Trendline fitted using the least squares method and a logarithmic function. The relationship is significantly different than zero ($p<0.01$).

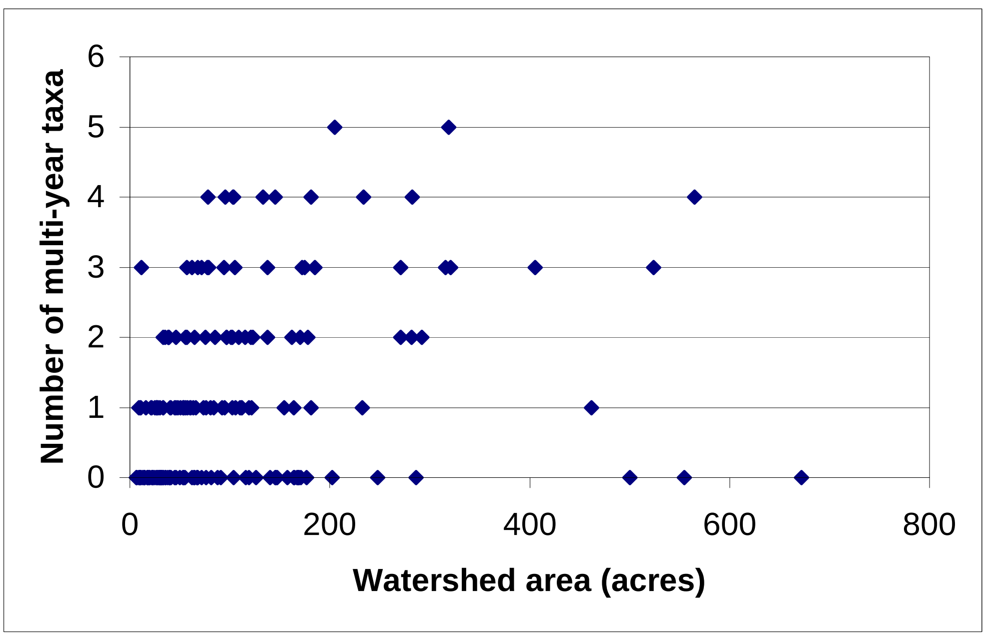


Figure 8. Number of taxa collected in each sample that live greater than one year in the aquatic life stages, versus watershed drainage area at each sample location.

Aquatic Ecosystem Enhancement at Mountaintop Mining Sites

About the Mountaintop Mining/Valley Fill Environmental Impact Statement
The U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers (Corps), U.S. Office of Surface Mining (OSM), and U.S. Fish and Wildlife Service (FWS), in cooperation with the State of West Virginia, are preparing an Environmental Impact Statement (EIS) on a proposal to consider developing agency policies, guidance, and coordinated agency decision making processes to minimize, to the maximum extent practicable, the adverse environmental effects to waters of the United States and to fish and wildlife resources from mountain top mining operations, and to environmental resources that could be affected by the size and location of fill material in valley fill sites. The draft EIS will be released for public comment during the summer of 2000. The final EIS is slated for completion by January 2001.

Early in 1998, the four Federal agencies now involved in the EIS formed a work group and agreed on a series of priority areas where more information and analysis would assist them in regulating the effects of valley fills associated with mining operations. Study plans were adopted and funded for undertaking valley fill inventories in West Virginia, Kentucky, and Virginia; for assessing the stability of valley fills; and for assessing the potential for downstream flooding from these mining operations. The agencies also placed priority on studying the impacts of valley fills on aquatic habitat; on surveying and evaluating mitigation practices being employed in West Virginia and neighboring Appalachian Coalfield States; and on evaluating how to better coordinate the Federal regulatory programs. These studies were underway or in the planning stages when the Bragg v. Roberston settlement agreement was reached.

With the decision to prepare an EIS, the agencies brought the coordination of these technical studies under the scope of the EIS, and broadened state participation. The expanded network of agencies has now examined the studies initiated in 1998 and has modified those study plans to make them more useful for the EIS. Additional work plans responding specifically to the EIS mandate have also been drafted.

Team leaders have been selected among the participating agencies for each of the technical study areas, which are listed below. The team leaders worked with a team representative of the expertise of each agency to develop a work plan. The work plans reflect what the agencies believe should be studied, and are subject to revision as work progresses and new insights are gained.

EIS Technical Study Areas:
- Future Mining
- Fill Stability
- Mining and Reclamation Technology
- Flooding Potential
- Fill Hydrology

- Streams
- Fisheries
- Wetlands
- Aquatic Ecosystem Enhancement
- Terrestrial Ecology
- Soil Quality and Forest Productivity
- Socioeconomic Issues
- Mine Dust and Blasting Fumes
- Landscape Ecology/Cumulative Effects

Prelude to the Symposium

The Team Leader for Aquatic Ecosystem Enhancement submitted a work plan for this technical study area to the EIS Steering Committee in July 1999. The work plan, which is available from the EPA Region III internet site containing information related to the EIS (http://www.epa.gov/region3/mtntop/index.htm), identified the goals of the EIS related to Aquatic Ecosystem Enhancement:

- Assess mining and reclamation practices to show how mining operations might be carried out in a way that minimizes adverse impacts to streams and other environmental resources and to local communities. Clarify economic and technical constraints and benefits.
- Help citizens clarify choices by showing whether there are affordable ways to enhance existing mining, reclamation, mitigation processes and or procedures.
- Identify data needed to improve environmental evaluation and design of mining projects to protect the environment.

The Aquatic Ecosystem Enhancement work plan was designed to augment the activities of the Streams and Fisheries Survey work plans and build upon the symposium held under the Mining and Reclamation Technology work plan in June 1999. The work plan included components to evaluate current stream practices and to evaluate opportunities for aquatic ecosystem enhancement using existing information, field monitoring, surveys, and expert reviews. The work plan proposed a workshop (subsequently changed to a symposium) of experts in ecology and stream restoration to review the current practices at specific sites selected by the mining companies and to outline the factors that would contribute to successful stream restoration and aquatic ecosystem enhancement.

An Aquatic Ecosystem Enhancement planning meeting was held September 15, 1999 to outline plans for the symposium on stream restoration and reclamation practices being used at valley fills and mountaintop mines. A panel of experts was selected to tour several mine sites to evaluate the restoration and reclamation practices being used at those sites. The National Mine Land Reclamation Center in cooperation with the West Virginia Mining and Reclamation Association and the West Virginia Coal Association recommended four sites to be visited by the panel of experts and serve as representative samples of current practices. The site visits occurred during the period December 7-8, 1999 at Elk Run Mine of Massey Coal; Samples Mine of Catenary Coal; Rollem Fork Mine of Pen Coal; and Hobet 21 Mine of Hobet Mining a subsidiary of Arch Coal.

The symposium followed on January 12, 2000 to offer a forum for presentation of the views and recommendations of the panel of experts for aquatic ecosystem enhancement at mountaintop mining sites. The symposium also offered an opportunity for public input, primarily from the mining and reclamation industry, on the barriers (regulatory, financial, or technical) to enhanced reclamation. The symposium was held open to the public, with no registration fee, at the Holiday Inn, Charleston House, in Charleston, West Virginia.

Symposium Attendees

A total of 162 persons registered their names and affiliations to attend the symposium. A complete listing of the registered attendees is included in this proceedings.

The largest group registered included 98 representatives of the coal mining industry along with their suppliers and consultants. The next largest group included 43 members of the government and regulatory community representing the following federal and state agencies; U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, U.S. Office of Surface Mining, U.S. Geological Survey, West Virginia Division of Environmental Protection, West Virginia Division of Natural Resources, Virginia Department of Mines, Minerals, and Energy, Kentucky Division of Water, and the Kentucky Department of Fish and Wildlife Resources.

There was a notably low turnout from the environmental advocacy community and the general public. However, considering the scientific and technical nature of the program, this was not considered to be detrimental to achieving the symposium objectives. The discussion that transpired between the panel of experts on aquatic ecosystems, the mining industry, and the regulatory community yielded numerous potential enhancements to aquatic resources at mining sites and the barriers to their implementation that will require further evaluation as part of the EIS process.

Panelist and Key Person Biographies

Paul F. Ziemkiewicz

Paul Ziemkiewicz is a native of Pittsburgh, PA. He received BS and MS degrees from Utah State University in biology and range ecology, respectively. He then received a Ph.D. from the University of British Columbia in Forest Ecology.

After graduating from UBC in 1978, he joined the Alberta Government's Department of Energy. There he directed its reclamation research program in coal and oil sand mining. He also served on Alberta's regulatory review committee and served as the research manager of the Province's coal research program. In 1988, he came to West Virginia University to serve as the Director of the National Mine Land Reclamation Center and the West Virginia Water Resources Research Institute.

He presently serves on a number of federal, state and industry advisory panels on environmental remediation. Dr. Ziemkiewicz has over 70 publications on the topics of mine land reclamation, acid mine drainage, and coal ash application in mines.

J. Bruce Wallace

J. Bruce Wallace received his BS from Clemson University, and MS and Ph.D. from Virginia Tech. He is currently Professor of Entomology and Ecology, University of Georgia in Athens, Georgia, where he teaches courses in stream ecology, aquatic entomology, and immature insects. He has served as major professor of some 38 graduate students at the University of Georgia. Dr. Wallace is author, or co-author, of some 150 scientific papers, including book chapters, concerned with various aspects of stream ecology or aquatic entomology.

Much of his research during the past 25 years has been conducted on southern Appalachian streams at the Coweeta Hydrologic Laboratory (U.S. Forest Service) in western North Carolina and supported primarily by the National Science Foundation. His primary research areas include: linkages between streams and terrestrial ecosystems; role of aquatic invertebrates in stream processes; effects of disturbance and recovery of streams from disturbance; secondary production and aquatic food webs and energy flow; and, organic matter dynamics in headwater streams.

Dr. Wallace is a past president (1991-1992) of the North American Benthological Society. He was the recipient of the 1999 Award of Excellence in Benthic Science from the North American Benthological Society.

D. Courtney Black

D. Courtney Black is the Program Manager for the National Mine Land Reclamation Center at West Virginia University. Mr. Black is a scientist with 6 years of research and project management experience. His primary focus has been in the fields of coal combustion product utilization and field scale acid mine drainage treatment. Mr. Black also serves as the Director of West Virginia University's National Environmental Education and Training Center. NEETC's primary focus is to ensure that health and safety concerns are incorporated into new environmental remediation technologies.

Peter Lawson

A native of County Durham, England, Peter Lawson received his undergraduate degree in Mining Engineering in 1978 from New Mexico Tech. In 1986, while maintaining full time employment in the mining industry, he received his MBA from Ashland University, Ohio. Mr. Lawson has more than 20 years of industry experience, the majority of which has been in surface coal mining in Appalachia. During his career he has worked on projects in western Canada, Russia and Mongolia, as well as having performed work in virtually every major coal-producing basin in the United States. Arch Coal, Inc. has employed Mr. Lawson for 5 years where he is currently President and General Manager of Catenary Coal Company. Catenary Coal Company has received numerous awards for the Samples Mine in Kanawha County where the company's achievements and approach to reclamation have been recognized at both state and national levels. Catenary Coal Company is twice winner of the David C. Callaghan Award, winner of the IMCC National Reclamation Award, and winner of the West Virginia Ducks Unlimited Wetlands Award.

John S.L. Morgan

John S.L. Morgan is an environmental mining consultant with extensive experience in both surface and underground mining for the extraction of metalliferous ores, coal and industrial minerals. He has a specific emphasis on the environmental effects of mining and mine reclamation. He also provides detailed technical expertise in the analysis of mine subsidence prediction and mitigation, acid mine drainage and mine planning.

Mr. Morgan founded Morgan Worldwide Mining Consultants, Inc. in 1995. Previously, he had established Morgan Mining & Environmental Consultants, Ltd. in 1990 with a staff of 18 people and built it into a $2 million per annum operation with 27 employees. The International Mining Consultants Group acquired the company in 1992. Mr. Morgan then served as the Executive Vice President of Weir International Mining Consultants until 1995 when he left to form Morgan Worldwide Mining Consultants, Inc.

Mr. Morgan has been the project manager for a number of mine technical reviews, for a significant number of subsidence investigations, and for environmental compliance and liability analysis reviews for both operating and abandoned mining operations. He is actively involved in projects in all regions of the United States, and has worked in Russia, Indonesia, Ukraine, Poland, Bulgaria, Peru, Argentina and Trinidad. During his career, Mr. Morgan has also worked in rock mechanics in South Africa, and as a planning engineer for open cast coal mining in Britain.

Horst J.Schor

Mr. Schor's educational background includes degrees in Civil Engineering and Geography and Graduate Course work in Environmental Studies.

His professional career spans more than 25 years during which he managed the development of large scale hillside planned communities in Southern California and other projects. Since 1991 he has been an independent consultant serving the private and public sectors on issues of land development, landform restoration and mining reclamation with particular emphasis on geomorphological restoration.

In recent years he has been a consultant to Syncrude Oil of Alberta, Canada re-designing large scale tailing deposits from tar sands excavations to give them natural landform characteristics. Mr. Schor has also been engaged by the State of Kentucky Environmental Protection Agency Water Quality Division, the State of Virginia Department of Minerals, Mines and Energy and the Navajo Nation Environmental Protection Agency to study coal mining reclamation practices in their respective states and make recommendations for improvements.

He is a regular guest lecturer at The University of Wisconsin College of Engineering and most recently was invited to speak at the University of Dresden, Germany.

Rocky Powell

Rocky Powell is the founder and principal of Clear Creeks Consulting, an environmental firm specializing in stream and watershed assessment, management, and restoration. Mr. Powell has over 25 years in the environmental field with experiences that include wildlife and fisheries research, water quality monitoring, natural resources protection, watershed management, stream assessment and restoration, and teaching. Providing environmental consulting services in Maryland, Virginia, West Virginia, North Carolina, Pennsylvania, New York, Vermont and Texas, Mr. Powell has: 1) conducted hundreds of geomorphic watershed and stream assessments; 2) developed watershed management plans; and 3) designed, permitted, provided construction supervision and post-construction monitoring for numerous wetland mitigation and stream restoration projects.

An instructor in the Johns Hopkins University School of Continuing Studies from 1992-1999, he taught graduate and undergraduate courses on stream ecology and stream related issues. He has presented numerous workshops and short courses on stream dynamics, stream protection, assessment, management, and restoration throughout the United States and Canada.

Randy Maggard

Randy Maggard is an Environmental Specialist and Surface Mine Engineer with Pen Coal Corporation. He has degrees in Chemistry and Civil Engineering and has been employed with Pen Coal for the last 14 years. He has been active in environmental affairs related to coal mining and is a member of the West Virginia Surface Mine Drainage Task Force. Pen Coal has received numerous reclamation awards for their operations in West Virginia and Kentucky. Pen Coal has been conducting extensive biological monitoring for the last five years on their Kiah Creek operation located in Wayne, Lincoln, and Mingo counties in southern West Virginia.

Steven N. Handel

Steven N. Handel is a restoration ecologist interested in the establishment of native communities on degraded lands. He serves as professor of ecology and evolution at Rutgers University in New Jersey, where he teaches and does research in the fields of plant ecology, plant-animal interactions, and restoration. Dr. Handel is Director of the new Center for Restoration Ecology at Rutgers. He also has been a biology professor and Director of the Botanical Garden at Yale University. He serves as an editor for the journal Restoration Ecology, and was elected chair of the Plant Ecology Section of the

Ecological Society of America. Trained at Cornell University, he and his students have done fieldwork throughout the east coast. As a consultant, he has advised on restoration design on degraded sites such as urban landfills, urban parks, sand mines, and national parks affected by invasive species.

Ben B. Faulkner

Ben B. Faulkner served as a surface mine reclamation inspector for the West Virginia Division of Natural Resources, dealing with inspection, enforcement, and permit review in many southern counties. He has served as an industry biologist and has coordinated reclamation and environmental affairs. He has been a research associate at West Virginia University in the fields of mine reclamation and mine drainage. As a private consultant, he has conducted training seminars for inspectors and operators in AMD prevention, and chemical and passive treatment.

As sole proprietor of Bratton Farm, he has provided professional consulting services to several international corporations and agencies. He has prepared surface mine, deep mine, and other permits and provided environmental management services including designing, installing, and monitoring numerous wetlands, anoxic limestone drains and other passive treatment systems for WVDEP, WVU, and industry. He has performed numerous benthic studies for industry and WVDEP. He serves as a special consultant to WVDEP for acid mine drainage issues.

Welcome and Introduction
Dr. Paul Ziemkiewicz

Dr. Ziemkiewicz, Director of the National Mine Land Reclamation Center and West Virginia Water Research Institute at West Virginia University, welcomed the attendees and explained the format of the symposium. He emphasized that the gathering was a technical symposium on improvements to current mining and reclamation techniques that will enhance the aquatic ecosystem. Furthermore, he made it clear this was not a forum to debate the practice of mountaintop mining.

He went on to describe two colossal coal refuse failures from mining history (Aberfan, Wales and Buffalo Creek, West Virginia) that resulted in many deaths and that led to most of the current regulations regarding the technical design of valley fills. These current regulations emphasize drainage through the fill materials and discourage standing water, such as ponds and streams, which affect the margin of safety for fills. Thus, he expressed the opinion that environmental considerations were not a major driver for the current regulations- safety was the paramount concern.

However, state-of-the-art in geotechnical engineering has advanced to the point that valley fills that include some streams and ponds in the final design could be safely considered, according to Dr. Ziemkiewicz. He introduced the symposium attendees to a group of distinguished experts who will suggest practices that may enhance the resulting aquatic ecosystem downstream from valley fills. He also noted that during the breakout sessions everyone would have an opportunity to identify barriers to implementing these enhanced practices.

Overview of First Order Watersheds
Dr. Bruce Wallace

Dr. Wallace provided a scientific view of the role of first order watersheds in the ecosystem and the impact of mountaintop mining with valley fills. Dr. Wallace highlighted data from ongoing experimental and descriptive studies of southern Appalachian watersheds and stream processes at the Coweeta Hydrologic Laboratory in western North Carolina where he has been working for 25 years. According to Dr. Wallace, the eighty kilometers of small headwater streams on this area owned by the U.S. Forest Service are much like the streams found in the central Appalachian region around mountaintop mining areas. He pointed out that organic material in these streams is the most important source of energy for downstream areas. He commented that nearly eighty percent of this energy comes from the detritus (decomposed organic material) from the surrounding forests.

Dr. Wallace noted that small streams in the ecosystem:

- Have maximum interface with the terrestrial environment with large inputs of organic matter from the surrounding landscape
- Serve as storage and retention sites for nutrients, organic matter and sediments
- Are sites for transformation of nutrients and organic matter to fine particulate and dissolved organic matter
- Are the main conduit for export of water, nutrients, and organic matter to downstream areas

He continued his presentation by noting that benthic organisms that shred course organic material and woody debris increase the rate of fine particulate and dissolved material that is exported downstream. He explained that leaves that enter the stream are first colonized by bacteria and fungi and then the invertebrates eat the microbially conditioned leaf material. Next he noted that these biota assimilate less than ten percent of the organic material they consume allowing the remainder to pass back into the stream. Thus, according to Dr. Wallace, the resulting fine and dissolved organic material is much more amenable to downstream transport with less than two percent of organic material continuing downstream as course particulate.

Diversity of detritus is essential to the production of organic material for release downstream, according to Dr. Wallace. He noted that different types of leaves decompose at different rates and tend to be in harmony with the different biota lifecycles in the nearby streams. One experiment that he participated in at Coweeta constructed a canopy over a segment of stream to preclude certain types of leaf material from the stream. He summarized the experimental conclusion that after six years with this cover in place, the Coweeta stream had the lowest secondary productivity of any stream recorded in the world, including many located in the Arctic tundra. Thus, according to Dr. Wallace, diverse detritus material is very important to the production of organic energy in the stream and this is one reason we should be considering a diverse array of detritus resources at a reclamation site and not just a single species of rapidly decomposing material.

Dr. Wallace further described experiments at Coweeta covering more than eleven years that have compared the rate of decomposition in treated streams [treated with insecticide], where there is less than a full complement of benthic invertebrates, to decomposition in untreated or natural streams. Based on the large quantity of data accumulated, he and others concluded that it took more than twice as long in the treated streams to decompose the same amount of organic material compared to the untreated streams. This led Dr. Wallace to the conclusion that reducing the number of invertebrates reduces the amount of decomposition and, as a result, the amount of fine particulate and dissolved organic material that is transported downstream. Furthermore, he noted that when the treatment was ended, there was rapid recolonization of invertebrates, which restored the downstream transport of organic material.

According to Dr. Wallace, measurements made at the Coweeta Laboratory over a period of fifteen years determined that the first and second order streams from this area provide more than fifty metric tons of fine particulate and dissolved organic material to the downstream reaches. Dr. Wallace noted that this amorphous detritus, as it is referred to in the downstream waters, is a major food source, especially for filter feeders, which eventually affects the entire food chain. He concluded his remarks on this experiment by stating that this organic material, which originated in the first and second order watersheds, represents more than eighty percent of the food supply for some downstream species.

Dr. Wallace explained that the measure of retention of organic material in watersheds is described by a term called "spiraling length, " which is the distance traveled by organic matter before its uptake by some organism and later reintroduction into the stream. He noted that this distance tends to be very short in headwaters, on the order of a meter, and very long downstream, usually several kilometers. Thus, Dr. Wallace concluded that organic material is retained for long periods of time in the first and second order watersheds where it is produced.

Temperature ranges for headwater streams throughout the seasons tends to be very important, stated Dr. Wallace. He explained that the growth of organisms is dependent on the cyclic temperature of the water, cueing many lifecycle events- pupation and mating, for example. Dr. Wallace highlighted the fact that the water coming from the toe of a valley fill tends to be at a mean annual temperature rather than at a seasonally appropriate temperature, which adversely affects the growth cycle of many stream organisms. Dr. Wallace expressed the opinion that leaving the ponds intact below the fill may help replicate the annual thermal variation further downstream. This idea will be explored further during the breakout sessions.

Dr. Wallace provided the following summary of the major roles of headwater streams in two categories, physical and biological:

Physical

- Headwater streams tend to moderate the hydrograph, or flow rate, downstream
- They serve as a major area of nutrient transformation and retention
- They provide a moderate thermal regime compared to downstream waters- cooler in summer and warmer in winter
- They provide for physical retention of organic material as observed by the short "spiraling length"

Biological

- Biota in headwater streams influence the storage, transportation, and export of organic matter
- Biota convert organic matter to fine particulate and dissolved organic matter
- They enhance downstream transport of organic matter
- They promote less accumulation of large and woody organic matter in headwater streams
- They enhance sediment transport downstream by breaking down the leaf material

- They also enhance nutrient uptake and transformation

Dr. Wallace made the additional point that small headwater streams in the Appalachians often harbor unique biota. According to Dr. Wallace, Morse et al. (1997) consider 19 species of mayflies, 7 species of dragonflies, 17 species of stoneflies, and 38 species of caddisflies to be vulnerable to extirpation at present in the southern Appalachians. He noted that many of the rare species are know from only one or two locations in springs, brooks or seepage areas. Furthermore, he stated, many small streams, seeps, springs, and brooks have not been fully explored. Dr. Wallace provided the following reference citations on this aspect of first order watersheds.

Morse, J. C., B. P. Stark, W. P. McCafferty, and K. J. Tennessen. 1997. Southern Appalachian and other southeastern streams at risk: implications for mayflies, dragonflies, stoneflies, and caddisflies. pp. 17-42, in: G. W. Benz, and D. E. Collins (eds.) Aquatic Fauna in Peril: The Southeastern Perspective. Special Publication 1, Southeastern Aquatic Research Institute, Lenz Design and Communications, Decatur, GA. 554 p.

Morse, J. C., B. P. Stark, and W. P. McCafferty. 1993. Southern Appalachian streams at risk: Implications for mayflies, stoneflies, caddisflies, and other aquatic biota. Aquatic Conservation: Marine and Freshwater Ecosystems 3:293-303.

Mine Site Visit Report

Courtney Black

Mr. Black summarized the tour taken by the experts to four mine sites on December 7-8, 1999. By way of introduction, Dr. Ziemkievicz made note that while we have many distinguished experts on these issues in West Virginia, introducing some outside experts may help us to generate some new ideas for consideration. Mr. Black organized the visits as a means of introducing the panel of experts to actual mountaintop mining and reclamation practices and the environmental conditions that result.

Mr. Black made note that the sites visited were:

- Elk Run Mine, operated by Massey Coal
- Samples Mine, operated by Catenary Coal Company
- Rollem Fork Mine, operated by Pen Coal
- Hobet Mining 21, operated by Hobet Mining, a subsidiary of Arch Coal

Mr. Black presented a number of photographs taken during the visit. His presentation is included with this proceedings. The images he presented from Elk Run depict several valley fills, sediment ponds at the toe of the fills, and downstream reaches. He noted there was evidence of water retention in the sediment ditches that could support aquatic resources. He commented that the experts had observed an experimental area where the backfill material was not heavily compacted to promote the growth of vegetation.

According to Mr. Black, Massey Coal also produced rolling landforms in the some of the fill areas that differed from the typical engineered fill site in slope gradient and benching.

Mr. Black commented that at the Samples Mine, the experts viewed an in-stream pond constructed by Catenary Coal Company. Several species of insects had been introduced into this pond to rebuild the ecosystem, according to Mr. Black. Mr. Lawson described this site in more detail during the next presentation.

Mr. Black stated that at the Rollem Fork Mine, being developed by Pen Coal, a large amount of toxic materials handling and encapsulation work was necessary based on the pre-mining conditions. He further noted that Pen Coal created a number of combination ditches for storm water and sediment control and that these are required to be removed within a specified time period after the site is closed to comply with existing regulations. During the site visit, the experts inquired if the ditches that contain developed wetland activity can be left intact after site closure. According to Mr. Black, the experts also observed several nontraditional landscape profiles. Mr. Black commented that at the Frank Branch portion of the mine site, several species of trees were observed including pines and Russian olives with evidence of natural succession underway.

Mr. Black described the Hobet 21 Mine site, a twenty-year old mining operation that offered views of more established reclamation sites. According to Mr. Black, one observation made by the experts was that there were too few species present. He noted that excavation by the large dragline coincidentally added some rolling landform profiles. As at the other sites, he commented that there was evidence of developing aquatic ecosystems that would have to be removed before release of the closure bond.

Catenary Coal's Success in Restoring Aquatic Habitat

Peter Lawson

Mr. Lawson began his presentation by noting the broad significance of the EIS and the potential impact on coal mining in West Virginia and throughout the country. Mr. Lawson spoke about four topics related to the Samples Mine operation; the scope and background of the Samples Mine, structures that are constructed as a condition of permits and two enhancement projects, the G-Ponds and the Abandoned Mine Land Mitigation Project.

Mr. Lawson began with the history of the site. He noted that the Samples Mine land was acquired by the company in 1989 and developed to the point of full production in 1995. In the year 2000, he expects to extract approximately 6.5 million tons of coal from the site and move about 95 million yards of overburden. According to Mr. Lawson, the site employs about 500 full-time employees and contractors.

He stated that all runoff from a mining site has to be diverted to runoff ponds that meet NPDES discharge permit conditions further downstream. He noted there are required structures that include both in-stream ponds and on-bench structures, including ditches and shallow ponds. According to Mr. Lawson, current law requires that these be designed to handle major storm events ranging from 10-year, 24-hour storms up to 100-year, 24-hours storms. At Samples Mine, he noted that Catenary Coal Company has completed construction of 23 in-stream ponds with 275 acre-feet of storage capacity at a cost of about $2.5 million dollars. He also commented that upstream ponds tend to accumulate any sediment from the mining operation and many of the downstream ponds are completely free of sediment and provide excellent aquatic habitat. They have also completed 4,300 linear feet of on-bench structures at the site. Mr. Lawson highlighted one in-stream pond that was built at the toe of a fill in a previously ephemeral or intermittent portion of the landscape that now provides perennial water flow. He noted that many of the on-bench structures also contain water year around and provide excellent habitat for vegetation, aquatic organisms, and water fowl.

The G-Ponds enhancement project, continued Mr. Lawson, is a combination of structures constructed in between two consecutive ridges to enhance the post-mining land use. He described the southern most ponds as shallow to attract wading birds and to give them refuge from the coyote, bobcat, and bear that have moved back into the area. The northern ponds, he explained, have deep pools to promote fish spawning and have floating nests for geese. These ponds are fed by both above ground and underground water sources according to Mr. Lawson. He noted that Catenary Coal used what they have termed “starter kits” of aquatic organisms including bass, bluegill, yellow perch, native minnows, crayfish, bull frog tadpoles, snails, clams, and water fleas. According to Mr. Lawson, they also added duck potatoes, water lilies, soft stem bull rush and cat tails along with red and silver maples, pin oak, and white pine. Mr. Lawson presented photographs showing the site being used last summer for an employee picnic when the ponds were stocked with sport fish.

Prior to acquisition of the land by Catenary Coal, continued Mr. Lawson, surface and underground mining had occurred on the site up until the mid 1970s and there were three large, abandoned refuse piles, covering about 155 acres and containing ten million yards of refuse, that needed to be reclaimed. Reclamation of these sites was beyond the scope of the original permits, according to Mr. Lawson, but offered an opportunity for mitigation of stream loss as a result of the Samples Mine valley fills. He also noted that reclamation provided immediate and long-term benefits to the community by improving the quality of water flowing into the Cabin Creek watershed. He explained that during heavy rains there was uncontrolled heavy flow and resulting black water in the adjacent stream and there were also large areas around the site producing acid-mine drainage. He stated that the site was graded and a large amount of cover material and topsoil was brought into the area taking care to protect the natural or volunteer vegetation that had developed over the years. He discussed the drainage channels that were installed to control the runoff and the wetland that was constructed to treat the acid-mine drainage with a series of four limestone cells, along with a relocated stream channel. He noted that vegetation was added to the wetland for biologic treatment and polishing cells were added to improve the quality of the water exiting the system.

As an introduction to the next portion of the symposium, Mr. Lawson highlighted a misperception that mountaintop mining operations using draglines leave large flat areas with monolithic structures uncharacteristic of the Appalachian region. At the Samples Mine, he pointed out, the dragline was used to move overburden from one area to another and lift the elevation of the material to an average of about 225 vertical feet of relief above the lowest coal seam being mined. This could not be economically accomplished by a truck and shovel operation at this site according to Mr. Lawson. Photographs presented by Mr. Lawson showed how this is being accomplished at the Samples Mine.

Mr. Lawson expressed the opinion, which he supported by several photographs, that the mining industry has become very good at the reclamation of sites in accordance with the approved post-mining land use, including fish and wildlife habitat.

Panelist Recommendations

The seven experts that toured the mining sites were each provided an opportunity to introduce their individual and collective perspectives on the subject of Aquatic Ecosystem Enhancement. These remarks are grouped into three areas (Landforms, Aquatic Resources, and Vegetation) with corresponding breakout sessions later in the symposium. Each topical area was followed by a brief question and answer session with remaining questions deferred to the breakout sessions.

Landform

Horst Schor and John Morgan

Comments by Mr. Schor

Mr. Schor described his interest as the changes in landform that take place when man makes use of the land for some purpose. Much of his work evolved as a response to urbanization on the west coast but his work has become of interest around the world as people deal with issues similar to mountaintop removal mining in Appalachia. The photographs he presented depict the radical alteration of the landscape with the resulting man-made landforms that coincidentally alter the hydrology into a sheet flow pattern. He noted that the progressive erosion of these man-made sites typically changes the site back toward a natural system of radial patterned swales. He suggested that reclamation of the site to natural landform analogs with vegetation concentrated in the swales is more visually appealing and more stable in the long-term. The concentration of moisture in the swales and focusing the development of vegetation in these areas promotes a more sustainable ecosystem, according to Mr. Schor.

Mr. Schor noted the distinction in the post-mining land forms at surface mines and at mountaintop mining operations. Surface mines, he observed, tended to retain much of their natural relief (elevation and contour) while there was a dramatic change to the relief at mountaintop mining sites. He noted that the reformed land shapes tend to promote sheet runoff across large areas channeled into streams without much transition from top to bottom. He also noted that Catenary Coal had succeeded in recreating a ridgeline in a man-made landform. The next step toward his concept of natural landform regrading, he explained, would be to also depress the valley fills recreating a natural runoff path. According to Mr. Schor, an example of this concept was designed into the Pine Creek Branch valley fill in Kentucky, which was permitted with a depressed valley fill design, but the fill has not yet been constructed.

Mr. Schor described a project he had recently completed for the Department of Power and Water, City of Los Angeles, which involved a half million-yard valley fill. In the photograph he presented, the main drainage path was a curvilinear pattern with radial drainage paths leading to it throughout the length of the run. The benefit of the project, according to Mr. Schor, was that the Corps and the FWS granted credit for wetland and riparian woodland habitat mitigation where the project had concentrated runoff in the swaled areas, thus avoiding the cost of going off-site to achieve mitigation. He noted that depressing the valley fill and raising the ridgelines would affect the areal size of the fill. However, he also noted that, based on the information he gathered during the tour, these valley fills only account for about thirty percent of the total backfill material handled at the sites. He expressed the opinion that it should not affect the cost of the operation substantially. Based on his experience with the Los Angeles project, Mr. Schor explained that depressing the valley and raising the ridgeline caused only a ten percent reduction in the holding capacity of the design fill.

Comments by Mr. Morgan

Mr. Morgan pointed out that what the industry has been asked to do [reclamation] it has learned to do very well. According to Mr. Morgan, the objective of the symposium was to explore where we might alter the objectives of the industry during reclamation to satisfy environmental concerns regarding the resulting aquatic ecosystem. With the current valley fill design, commented Mr. Morgan, we are removing streams and replacing them with upland habitats that have far less aquatic resources. Mr. Morgan explained that there is currently no water on the backfill for a number of reasons including:

- Greater permeability in the mine spoil leading to greater infiltration
- Nothing to retard the flow during storm events
- No defined horizons within the backfill like in the pre-mining configuration
- No aquicludes until you reach the outcrop of the lowest coal seam.

Mr. Morgan presented a diagram of a model surface mining operation and explained that the water in the fill area infiltrates into the backfill material until it reaches the pavement under the lowest coal seam. The outcrop of this flow is typically at the toe of the valley fill, explained Mr. Morgan. He continued on to note that some surface water is captured in the surface drainage ditches but it also tends to quickly infiltrate. According to Mr. Morgan, in fill areas there are very few surface flows except during storm events and there are very few ponds allowed to remain on the backfill area. He expressed the opinion that this is driven by the objectives of the Approximate Original Contour (AOC) Model, which minimizes the areal extent of a valley fill based on geo-technical considerations.

Mr. Morgan proposes an alternate geometry for the placement of spoil in the valley fill area that allows the subsurface flow over the pavement horizon to emerge onto a low point of the valley fill. Identifying where this will occur and intercepting this subsurface flow will provide perennial flow further up the mountain, according to Mr. Morgan. He noted that the experts saw an example at the Pen Coal operation in Wayne County of the increased perennial flow from ditches down dip of the valley fill. Mr. Morgan proposed constructing more of a side-fill in the valley fill area tilting the face to one side, rather than a horizontal surface, to intercept the subsurface flow at a reasonably low gradient creating a stable surface aquatic resource. The disadvantage of this configuration, according to Mr. Morgan, is that you will have a concentration of water flow on one side of the fill and there will be regulatory concerns as you try to meet the 2:1 slope and 50-foot separation of benches on a side fill. There will likely be additional costs to place the side fill material further up on the hill, he explained. Mr. Morgan proposed a change to the AOC Model to allow the operator the flexibility to vary from the strict geometric approach and introduce landforming as a means of improving the aquatic habit in reclamation areas. He introduced a comparative study of the current AOC model and the alternative side fill configuration, which uses a volumetric definition for AOC, for a site in eastern Kentucky that had not been mined. According to his model, the side hill fill model actually covered less area because the backfill material was placed further up on the mountain. He further depicted a third phase to the AOC process to optimize the extent of the fill somewhere between these two solutions to allow the operator the flexibility to introduce additional landforming.

Questions and Answers

Mr. Schor and Mr. Morgan then entertained questions from the audience:

Q: [to Mr. Schor] Are you aware that the design surface water flows for this region [Appalachia] are much greater than in southern California? Also, our fills have a much greater volume than the example you showed. How do you know that your concept will work in this region and the fill will not all erode away?

A: Mr. Schor explained that the half million cubic yard project [for the City of Los Angeles] was only one example but is comparable in size to some of the valley fills in this area. Also, he explained, the last project he worked on was over 22 million yards of soil. With respect to the water flow, Mr. Schor continued, the criteria is how the drainage is concentrated into the tributaries; the larger water flow of this area would necessitate smaller concentration areas like smaller valleys. The person asking the question followed up that based on his extensive experience he has noted many fills constructed to the current design standard that could not withstand the extreme water flows of this area and failed.

A: Rocky Powell added that in his presentation later he would draw a comparison between pre-mining morphology and post-mining conditions. Mr. Powell noted that in post-mining conditions the ecosystem is changed from forested watersheds to grasslands. Additionally, he explained, we have reduced the time of concentration by departing from natural landforms, which has the effect of increasing erosion. He noted that restoring the natural landform and restoring the vegetation will increase the storage in the channel and convey the water in a more controlled manner.

Q: [to Mr. Schor] What requirements that the mining industry is currently under would have to be changed for your concept to be implemented at large-scale surface mines?
A: Mr. Schor replied that the operator would have to have relief from current design requirements for surface slope and bench requirements. According to Mr. Schor, examples of this were observed at the Samples Mine where they had not only restored the ridgeline but also did not have any benches. Furthermore, he commented, the equipment operator at this site explained his technique for preventing erosion was to grade the surface in a way that prevents the concentration of too much surface water- exactly as his theory suggests. Mr. Schor noted that the equipment operator had coincidentally developed this technique from field observation.

Q: [to Mr. Schor] What proportion of fill material would require rehandling or special handling to accomplish your concept?
A: Mr. Schor explained that this would be up to the operator but could actually be less. In a project he worked on in Virginia, explained Mr. Schor, the operator left two or three planned fill areas open. He thought the alternative concept might require an average of about thirty percent change in the amount of material handled.

Q: [to Mr. Morgan] What changes would you make to the AOC Model to accomplish your modified valley fill proposal?
A: Mr. Morgan explained that AOC calculates excess spoil that would require placement in a valley fill. He commented that the amount of material that is placed back on bench should be maximized. The volume of material placed in the valley fill should be minimized, according to Mr. Morgan, and not be greater than that calculated by the AOC Model. Mr. Morgan expressed the opinion that the operator should have the flexibility to put material where it best supports his operation.

Q: [to Mr. Morgan] Assume the mine is designed to AOC. Then you depress the valley fills and raise the ridgelines to construct natural landforms. This appears to increase the length of the stream affected. Please comment.
A: Mr. Morgan responded that this would be true in many cases. However, he noted, the issue of covering up a stream is a value judgement that should consider the quality of the original stream length. He concluded that the potential benefit from increasing the length of stream affected compared to the benefit of the proposed reclamation project is an issue that should be considered during the EIS process.

Q: [to Mr. Morgan] The AOC optimization approach conveyed in the slides does not reflect many of the necessary working conditions of a mining operation.
A: Mr. Morgan responded that the initial and additional material must be placed on the mined area.

Q: [to Mr. Schor] Are there other landforms possible for valley fills? For example, how about a finger ridge?

A: Mr. Schor replied that there are a myriad of alternatives for natural landforms.

Aquatic Resources

Rocky Powell, Dr. Bruce Wallace, and Randy Maggard

Comments by Mr. Powell

Mr. Powell prepared a written report, which is included as an appendix to this proceedings, containing his observations and recommendations from the tour of the four mine sites and he highlighted the report for the audience. Then he focused his remarks on the subject of stream channel morphology as he had mentioned during the morning session of the symposium.

Mr. Powell used a series of eight criteria to compare pre-mining and post-mining conditions of the aquatic ecosystems at each mine site:

- Are the valley and watershed characteristics consistent with pre-mining conditions?
- Is the vegetative cover consistent with pre-mining conditions?
- Have the soil characteristics been modified?
- Has the hydrologic regime been modified?
- Has the sediment regime been modified?
- Is channel morphology consistent with a natural, stable channel form?
- Have the physiochemical properties of the streams been altered?
- Have the biotic communities, trophic structure, and energy sources of the stream ecosystems changed?

He acknowledged that he had to rely on his experience with other watersheds in the region to complete the assessment due to the lack of pre-mining conditions for the mine sites that were visited. His report provides a detailed presentation of the regional watershed characteristics that were used as a pre-mining baseline for the assessment.

Based on his analysis, Mr. Powell concluded that the streams and ponds he observed did not serve to mitigate (replace the structure and function of) the original first and second order watersheds. Mr. Powell noted that the focus of his comments will be on enhancement, or improvement to the existing practices of mining and reclamation, with respect to aquatic resources. He pointed out that, in his opinion, the mining operators are doing a very good job of complying with current regulations and in many cases go beyond the regulations.

Mr. Powell commented that in the pre-mining condition, storm flows are moderate, runoff is minimal, and base flow is fairly reliable. The exception, he noted, is in shale and sandstone areas where flow may discontinue, especially during the summer. First and second order streams have base flow cross-sections where this base flow is channeled according to Mr. Powell. He explained these streams also have a flood surface where storm flows are channeled after they exceed the base flow section. In the post-mining condition, he noted, the reconstructed streams have little or no base flow and are designed to carry only storm flow and with a lack of base flow, there is no area for aquatics to live. He pointed out that there was evidence in the field that, with time, many of these constructed ditches and channels are evolving into a series of steps and pools. He also noted that the shape of the constructed channels is trapezoidal and designed to carry all the flow in one channel which differs from a natural channel. Mr. Powell showed pictures of several constructed channels and the erosion problems they endure including head cuts that travel up channel and scour erosion that travels downstream.

From an aquatic standpoint, Mr. Powell reiterated that without base flow there is little hope of establishing aquatic life forms. The mining industry, according to Mr. Powell, has constructed many storm flow channels that are very effective at handling storm flows and reducing the sediment loading on downstream water resources but do not contain base flow to support aquatic life forms. Mr. Powell expressed confidence, based on what he observed during the site visits and other recent study, that the mining industry could be successful in constructing natural channels with base flow capable of supporting aquatic organisms. Mr. Powell presented a number of examples of natural stream systems with various overall gradients, both steep and shallow, and explained how each had its own aquatic ecosystem. He also emphasized reclamation to natural channel flow with visual examples from several of his reclamation projects.

Comments by Dr. Wallace

Dr. Wallace followed Mr. Powell and provided his observations from the mine site visits. He started off by noting that he only observed flowing water in two places at the four sites that were visited. He commented that, perhaps, it is unrealistic to try to recreate lotic habitats in these areas. While he supports protecting every stream that exists, he noted that we may need to look to other values in these mined areas. He expressed the opinion that the trade off is between wetlands and headwater streams- they both have value. Headwater streams are a major feature in Appalachia, according to Dr. Wallace, while ponds and wetlands are relatively rare in this region. Furthermore, according to Dr. Wallace, streams normally have maximum interface with the terrestrial environment acquiring energy resources from the adjacent watershed whereas in ponds and wetlands the primary forms of energy are algae or plant material that enter the detritus food web. Streams have important linkages to downstream areas whereas wetlands vary, according to Dr. Wallace. Wetlands observed during the mine site visits, he continued, were not linked to the downstream watersheds- again, not that they do not have value but they do not replace the pre-mining streams. However, he noted, the wetlands do tend to limit the effect of disturbances on the downstream watersheds. Also, Dr. Wallace continued, the biologic communities found in streams tend to be indicative of disturbance whereas in wetlands this is much less so. Therefore, he concluded, trying to replace the aquatic resource of original streams may not be possible and there is certainly a trade-off between a reconstructed stream and a wetland.

One way to look at this tradeoff, stated Dr. Wallace, is in terms of minimizing the effect of valley fills on downstream reaches. He noted that the problem with the temperature coming from the base of a fill is that it is somewhat like a spring- nearly constant annual temperature. With a pond, Dr. Wallace noted, you will have exceptionally warm water in the summer and cold water in the winter. He expressed the opinion that we could redesign our ponds with larger shallow areas and increased throughput for the overall pond. Increasing the shallow zone, according to Dr. Wallace, will increase the amount of aquatic macrophytes and the benefits derived from them and the increased amount of wetland may also address the water chemistry problem that he hypothesizes to exist downstream from the toe of the valley fill. Dr. Wallace also noted that a number the sites have long straight stretches of drainage ditch that could be improved by creating a more natural, meandering run as proposed by Mr. Powell.

Changing the design of these wetlands, commented Dr. Wallace, simply by increasing the diversity of vegetation could improve the contribution to the ecosystem, particularly groundwater recharge. Also, he noted, creating an anaerobic condition as exists in many wetlands is an important contribution to denitrification and to transformation of sulfates in mine drainage to an immobile form- two important contributions to the quality of groundwater.

Dr. Wallace provided the following tabulation of some relevant comparisons of small streams and ponds or wetlands.

Headwater Streams	Ponds and Wetlands
Major features of the Appalachian landscape	Present, but rare in Appalachian landscape
Maximum interface with terrestrial environment	Less interface with terrestrial environment
Energy resources from adjacent watersheds as leaves, detritus, etc.	Primarily autochthonous primary production from algae and aquatic plants
Important energy links to downstream areas. Creeks and rivers strongly connected into a system	Rather closed energy system with less linkage, if any, to other areas, or downstream
Disturbance in headwaters can influence downstream areas	Little effects of disturbance on other ecosystems
Important retention and transformation of nutrients and organic matter	Can be important sites of nutrient storage and uptake provided sufficient littoral zone with plants
Biological communities (at least animals) often indicative of disturbance	Biological communities not as indicative of disturbance

Comments by Mr. Maggard

Randy Maggard summarized his views as consistent with the views of Dr. Wallace; do we want to try to replace intermittent and perennial streams or should we proceed with the development of wetlands and ponds? Mr. Maggard noted that someone had made the comment to him that there are no aquatic resources on reclaimed mine sites- only mud holes. He commented in reply that, while they may start off as mud holes, they do not remain mud holes. Mr. Maggard presented several photographs of sediment pond projects developed by Pen Coal. He indicated that his company has performed a number of studies that substantiated the aquatic resources that are present in these habitats and that they are improving over time.

Mr. Maggard provided three of these studies to the other experts of the panel for there use during the mine site visits. The document citations are presented below and the documents are included as an appendix to this proceedings.

Maggard, Randall and Ed Kirk. "Downstream Impacts of Surface Mining and Valley Fill Construction." Paper presented at the 1999 Annual Meeting of the West Virginia Acid Mine Drainage Task Force. Morgantown, WV. April 13-14, 1999

"An Evaluation of the Aquatic Habitats Provided by Sediment Control Ponds and Other Aquatic Enhancement Structures Located on Mine Permitted Areas in Southern West Virginia." Conducted for Pen Coal Corporation; Kiah Creek Mine Office; P.O. Box 191; Dunlow, West Virginia 25511. Prepared by R.E.I. Consultants, Incorporated; Ed J. Kirk Aquatic Biologist; 225 Industrial Park Road; Beaver, West Virginia 25813. November 23, 1999.

"Benthic Macroinvertebrate Study of Honey Branch, Its Sediment Control Ponds, and Its Influence on the East Fork of Twelvepole Creek Conducted 10/08/99" Conducted for Pen Coal Corporation; Kiah Creek Mine Office; P.O. Box 191; Dunlow, West Virginia 25511. Prepared by R.E.I. Consultants, Incorporated; Ed J. Kirk Aquatic Biologist; 225 Industrial Park Road; Beaver, West Virginia 25813. November 24, 1999.

Questions and Answers

The conclusion of Mr. Maggard's presentation was followed by a period of questions and answers on the subject of Aquatic Resources. Only one question was asked during this session.

Q: [to John Morgan] Do you see any situation where you can add streams or wetlands higher up on the hills in these fill areas? Is basal flow rare or can it occur at any site? Do you think from the number of West Virginia mining sites you have seen that this [basal flow] is possible at most sites?
A: As mentioned earlier, responded Mr. Morgan, it will be difficult to create basal flow at an elevation any higher than the outcrop of the lowest seam being mined. He continued by noting that the features that Randy Maggard showed are on the down dip side of the mined area where basal flow will typically occur. On most mine sites you will have some area where basal flow can be captured according to Mr. Morgan.

Vegetation

Ben Faulkner and Dr. Steven Handel

Comments by Mr. Faulkner

Mr. Faulkner began his remarks by noting that the only water that is consistently available around these sites is from the sediment channels down gradient from the surface-mined area and from the ponds and sediment structures below the valley fill. He commented that the valley fill provides a desirable source of water with near constant temperature and with plenty of dissolved oxygen that is of interest to the aqua culture industry. Furthermore, he continued, it is important to recognize that during the drought last summer the only source of consistent water flow in first and second order streams was from these valley fills. Although fills may change the appearance of the stream, it creates a different, not necessarily a worse, aquatic habitat according to Mr. Faulkner. He expressed the opinion that we should encourage leaving ponds on and below fills and encourage diversification of vegetation in and around the water courses to provide the shade and detritus that Dr. Wallace has identified as important to the ecosystem.

Mr. Faulkner described several practical and regulatory considerations for revegetation in and around drainage structures and watercourses.

1. Engineering considerations for hydrologic appurtenances.
   - safety considerations
   - erosion considerations
   - terrestrial and aquatic habitat enhancement
   - final reclamation considerations
2. Tree and shrub species for forestry and wildlife planting plans.
   - water availability and management
3. Natural succession on surface mines.
   - alien species vs. natives
4. Logistics and economics of revegetation and reforestation.

He noted that safety is of paramount consideration in surface mine development and reclamation. Mr. Faulkner commented that engineering watercourses for direction and retention of seepage and surface runoff must safely pass design storms. Furthermore, he continued, any efforts toward enhancement of the aquatic habitat provided by these structures must not compromise the safety or sediment control objectives of the structure.

Encouraging wildlife and aquatic life in watercourses and structures is generally of no negative influence on mining operations, according to Mr. Faulkner, with the exception of muskrats or beavers which may compromise the principal spillway elevation or interfere with bank stability. Seldom, he noted, can unreinforced grass covers be used in diversion ditches on steep slopes. Mr. Faulkner stated that where velocities exceed the maximum allowable for vegetative cover (3 fps), rock rip rap is used. He further stated that there is no comparison of cost, and slopes are kept as flat as possible to permit the lower velocities and cheaper grass banks whenever possible to control erosion. He identified two concerns in planting additional stems of shrubs or trees around sediment or drainage structures. First, the root system of woody vegetation, if planted in proximity to pipe conduits, will grow along those conduits compromising the integrity of the pipe and the compacted fill around it. Second, any plantings where water is impounded against compacted fill must be planned with this in mind.

Another concern in aquatic habitat enhancement, according to Mr. Faulkner, is that although the “long range” view is sought when selecting vegetation, one must realize that the long range (seral succession climax) of standing water in the Appalachian geology and geography associated with West Virginia is a grassy meadow and then a climax hardwood forest. Furthermore, he noted, there is no naturally occurring lentic community in the state with the exception of a one acre pond in the eastern panhandle. According to Mr. Faulkner, the future of all pools of standing water in the state (from man-induced activities, beaver dams, or inadvertent activity such as railroad or highway fills) is to be filled with sediment and become a meadow and then grow into a forest. He commented that established lentic aquatic habitat is present only for a limited time. Furthermore, he continued, there will always be a lotic community, but it will also change as the site ages. Additionally, he noted, increasing the number of woody stems around a lentic water body will accelerate the desiccation of the pool during periods of drought as the trees mature and their need for water increases. According to Mr. Faulkner, this will accelerate the natural succession of the water body to a meadow and eventual hardwood forest, actually reducing the number of years of lentic habitat and strongly influencing the remaining lotic habitat.

Mr. Faulkner commented that the lotic aquatic habitat on mountain-top mining sites is quite limited and that spoil swell necessitates steep slopes and watercourses or gentle watercourses over valley fill crests or backfill. This material, he commented, is so porous that it usually holds water only in response to significant precipitation events. The only location water can be found with some continuity is in down-dip sediment structures along the outcrop (sediment channels) or at the toe of the valley fills according to Mr. Faulkner. Generally, he noted, the only dependable lotic water is from the toe of the fill to the sediment pond, and this is generally a short distance. However, he continued, both these locations provide some dependable aquatic habitat which may be enhanced through land use and focused vegetation efforts.

During the drought in West Virginia this summer, the only first order watersheds with flow contained proven springs or valley fills according to Mr. Faulkner. The fills through their porous nature, he commented capture all seepage and runoff within the watershed and slowly release the water over a several month period, flattening out the wide runoff flows seen in an undisturbed or disturbed watershed. Generally, Mr. Faulkner commented, valley fill flows (at the toe) are oxygenated with reduced amounts of sediment and a constant temperature. He expressed the opinion that this constant, moderate temperature (generally about 55° F) is ideal for fish aqua culture. Substantial interest, according to Mr. Faulkner, has been raised about this resource in the state in the last few years including an extensive study and investment by the West Virginia Department of Agriculture and U.S. Department of Agriculture. Mr. Faulkner expressed the opinion that water quality at mines in West Virginia is generally of good quality, with only five percent of all NPDES sites requiring even occasional water quality attention.

The lentic habitat in shallow sediment ponds and channels can be made to be more beneficial for aquatic life with the planting of shrubs and trees to add detritus according to Mr. Faulkner. This coarse particulate organic matter, he noted, will be available to the shredder macroinvertebrates that will export fine particulate organic material downstream to the valley fill sediment ponds and receiving streams.

Mr. Faulkner stated that economics is of particular concern at drainage structures. Only a handful of hydrophilic woody stems are available from the state nursery according to Mr. Faulkner. He continued that the state nursery makes these plants available a full order of magnitude cheaper than commercial nurseries. He commented that state nurseries should be encouraged to provide additional viable species at a reasonable price. He also noted that substantial work was done on tree species, soil building and vegetation through the U.S. Department of Agriculture in the 1960's and 1970's and this material is available to the mine operator.

The sediment channels and valley fill ponds represent the best available aquatic habitat on surface mines, according to Mr. Faulkner, but they are often removed within a few years at the landowners request because of liability concerns. He stated that this complicated question will require a collective agreement between operator, regulator, and landowner.

In summary, Mr. Faulkner noted that fills on surface mines offer some significant benefits:

- a constant, moderate temperature and oxygenation which is optimum for aquatic life.
- Fills "meter out" water during drought.
- Fills provide "different" aquatic habitat (lentic) which is rare in mountains of West Virginia compared to plenteous lotic habitat.

He concluded that during reclamation we should encourage:

- Leaving ponds on and below fills.
- Planting diverse vegetation in/around watercourses to provide shade and detritus.

Comments by Dr. Handel

Dr. Steven Handel, a professor of ecology and evolution at Rutgers University, focused his presentation on the issue of landscape links and the potential of using natural landscape processes and links to restore and enhance wetland environments. Using the example of an oak woodland in West Virginia, Dr. Handel discussed the links between the first order streams and the surrounding terrestrial habitat. What can we do, he asked, in areas where there is sufficient base flow to support a first order stream to make them function in a manner similar to some of these natural streams? He added the question , how can we build on the natural ecological processes to rebuild self-sustaining natural landscapes at a minimum cost?

The difference between restoration ecology and landscaping is one of process and change according to Dr. Handel. He noted that for an ecologist the design has a wildlife value with a minimum amount of subsequent human involvement while a landscaper creates a human-dominated landscape with plants available from the commercial nursery. What the restoration ecologist plants to begin the process may all be gone in a few years according to Dr. Handel. He added that success is achieved when the original plants are replaced in natural succession by other self-sustaining native plants.

Dr. Handel highlighted that the value of small first order streams is enormous as has been pointed out today by others. He emphasized that his interest in these streams is based on their benefit to the surrounding wildlife. He noted that small ponds and flowing water attract wildlife to the area. While displaying photographs of a mine reclamation project and the rip rap lined drainage channels, he emphasized the opportunity to improve the surrounding ecosystem by encouraging the growth of vegetation. He rhetorically posed the question, how can we do this on very large sites that are engineered with large areas of grass and small clusters of trees? He responded that a concept that should be of interest to this audience is the idea of designing the site restoration to attract birds-natural landscapers. That design, he noted, includes perching, foraging, and nesting areas, and areas where they can find protection from their enemies.

He explained that his recent studies have considered the idea of encouraging natural succession by creating "islands" that attract natural seed dispersers (birds). Out west, he noted, people have experimented with the idea of transplanting an area of natural vegetation in a chunk on reclaimed mine sites. The experiment, he explained, included establishing twenty of these "islands" with traps under the trees to find out what types of seeds were being introduced into the area and are they appropriate natural succession plants. He continued to explain that samples taken during the first four months of the study collected approximately 14,000 seeds in a 65 square meter area including 26 native plant species that were not planted on the reclaimed site. This, he concluded, showed that this link in nature could be quickly established by providing a target for the birds to perch on and some remnant of the native vegetation in the surrounding area to provide the seeds. Of importance to this audience, he noted, is to know that the small pockets of native vegetation that are left intact at a site become a critical source of seeds to stimulate the subsequent natural succession during the reclamation process.

Seeds are only one part of reestablishing plant demography according to Dr. Handel. The quality of soil and the ground cover placed at the site are also important, he added, to the development of seedlings and eventual self-sustaining growth. He noted that there is general agreement that it is important to limit the amount of compaction of the top layers of soil at the site. He expressed the opinion that we must also modify the amount and type of ground cover that we place to control erosion, which is as important for proper development of the ecosystem as it is for the safety of the site. Deep rooted ground covers bind the soils and make space for the small seedlings of woody plants, he explained. He noted that this was discussed at the industry meeting last spring (1999) in Kentucky with the conclusion that operators must be trained to tread lightly on the land and to modify the types of ground cover used.

Dr. Handel also noted that diversity of vegetation is essential. He commented that the panel of experts observed many examples of wetlands on mine sites that are heavily populated with cattails. However, commented Dr. Handel, there was not sufficient diversity of vegetation. He continued to explain that what is missing are the blueberry, elderberry, willows and other shrubs and herbs that are typical of watercourses in the southeast where there is sun and adequate water. To get those back, he noted, we will have to jumpstart the process ourselves. He concluded with the comment that having only one species of plant is insufficient to promote natural succession because it will not attract a variety of birds.

Dr. Handel identified the presence of wild bees, which are essential to setting seeds and cultivating plants, as another consideration to enhance the natural succession process. There are over 8,000 species of wild bees in North America according to Dr. Handel. He explained that bees nest in soft ground or hollow trees and eat nectar and that simple modifications to encourage the habitat development of bees are necessary including the addition of flowering groundcover since grasses are all wind pollinated. Dr. Handel also noted that microbial processes in the soil are essential to the development of plant roots. He continued to explain that there are businesses that sell small packets of innoculum but we do not necessarily have to buy them. Sometimes, he noted, the necessary microbes will move back in by themselves if we have remnant forest areas near the mine site. Dr. Handel commented that studies have shown that in newly disturbed areas the amount of fungi on plant roots dissipated rapidly with the distance into the distressed area from the edge of site. He explained that this can cause the stressed nature of the woody plants and the inability of these plants to sustain growth. Dr. Handel noted that if we can hold, stockpile, and respread the original topsoil, we can retain these microbial populations and accelerate their reestablishment across the site.

Dr. Handel described an experiment that measured the ability of native plant species to grow on sites reclaimed with typical mixtures of rough grasses (fescue and Timothy). He explained that of more than 8,000 native plant species seeds only 130 seedlings were able to establish themselves in the soil and native grass mixture of a reclaimed site. The only species that were successful, he noted, were chokeberries, hackberries, dogwoods, spicebush, white oak, and sumac. He concluded that the typical mixture of rough grasses challenged the development of native species. Additionally, he noted that this further emphasized the interrelation of all the aspects of reclamation (seeds, groundcover, bees, "islands", water) and how they affect the resulting ecosystem.

Dr. Handel described the reclamation project at the Powell River site where the compaction had been carefully controlled and the topsoil stockpiled and remixed. He commented that this provided a good example of the more advanced reclamation techniques that lead to greater value for the landowner. He noted that increasing the value to the landowner for subsequent land use creates an important economic incentive that could translate into lower lease rates to the coal operator. He also pointed out a typical rip rap drainage channel and expressed concern that it is so commonly used throughout the region. According to Dr. Handel, there are situations where more suitable techniques may be used with little or no increased cost that would enhance the value of the water structure. He presented photographs of several alternative bioengineering projects that would replace rip rap. One example project, he noted, used organic fabric that will remain in place for several years until the plant growth is sufficiently established to protect the drainage channel from erosion. This particular example, according to Dr. Handel, had sustained two fifty-year floods in sequential years with no observable damage to the channel. Dr. Handel also commented that nursery stock may not have adequate biodiversity to develop a self-sustaining community. Accordingly, he concluded that we need a mixture of genotypes and these need to be reflected in our regulations.

He concluded his presentation by listing several environmental enhancement considerations to the hydraulic engineering that goes into a reclamation project:

- Create situations where restoration leads to reproduction
- Assembly of new communities
- Enhance invasibility by inviting natural dispersers
- Establish successional processes
- Meta-populations; linkages to the remnant forests that surround the site such as islands
- Buffer natural populations by having more plants in riparian zones
- Ecological processes
- Habitat links
- Cost effective management and monitoring

Dr. Handel commented that drainage channels and sediment ponds solve the engineering problems but they only create plumbing devices. He expressed the opinion that we would like to add to the hydraulic engineering concerns by introducing living restoration ecology solutions. Then together, he concluded, we can create a habitat that can begin to restore the ecological services we all depend on.

Questions and Answers

Dr. Ziemkiewicz expressed his observation that some of the recommendations appeared to be contradictory. For example, he continued, topsoil recovery preserves nutrients and, to some extent, the microbial population. He noted that many topsoils contain significant clay and spreading them on the surface can lead to significant compaction. He opened the question and answer session by raising the first question.

Q: [To the panel] Which is more important, the microbial population or the need for loose compaction? How many cases where topsoil is stockpiled do we see native plant populations subsequently emerge?

A: Mr. Faulkner explained that there is very little topsoil to begin with in so many areas and it is difficult to collect because of the roots and rocks. Furthermore, he noted that the desirable qualities of topsoil do not store well. He expressed the opinion that when topsoils are removed and subsequently remixed with spoil material very little of the microbial population will remain to support the desirable species.

C: Mr. Faulkner commented regarding Dr. Handel's point about bee populations. Mr. Faulkner explained that while there are many grasses on these reclaimed sites, we also have many plants that encourage pollinators such as trefoil and crown vetch. While many people dislike these ground covers, exclaimed Mr. Faulkner, they do have flowers for much of the growing season.

C: Dr. Handel responded to Mr. Faulkner with agreement that these flowering species are an enhancement. Dr. Handel also followed up on Mr. Faulkner's comments regarding topsoil by noting that topsoil is only a thin veneer above sandstone in mountain forests. Yet, he noted, these areas support huge forests suggesting that you do not need much topsoil. The issue is soil quality and not quantity according to Dr. Handel. Microbes are essential, he exclaimed, and studies have shown that you can create very healthy soils with only a small amount of topsoil mixed with crushed, weathered brown sandstone. Limiting the focus to the riparian zone, he continued, topsoil material would have to be introduced and minimizing the amount of compaction is critical. At one site, he observed, tilling the soil only six inches caused a dramatic increase in plant growth. On the point of stockpiling topsoil, Dr. Handel agreed that this can lead to anoxic conditions that damage the microbes. He concluded on this point by noting that some special handling is required to maximize the ecological value of the subsequent use of these topsoils.

C: Mr. Powell commented on the cost of restoration. He noted that there are many opportunities for stream restoration or creation of new streams. Creation of new streams at mountaintop mining sites, he stated, should not cause additional expense, it is a matter of changing the way the fill material is laid down. He also pointed out the difference of the higher gradient systems and that they require somewhat different techniques to control the energy of the stream compared to the bioengineering projects presented by Dr. Handel. In both cases, Mr. Powell concluded, the establishment of vegetation is essential to the long-term stability of the system.

Q: Mr. Morgan asked Mr. Powell for his opinion regarding sediment ponds and the value of multiple spillways, primary and emergency.
A: Mr. Powell explained that there may be benefit from changing some of the larger sediment ponds to shallow marshes with multiple channels to restore some lengths of channel.

C: Dr. Handel commented that it would be beneficial if we could find some way to increase the complexity or diversity of the streams. He added that this might include adding boulders, logs, snags, and channeling diversity that would have significant benefit to the development of the ecosystem and cost very little.

Q: [To the panel] What is the value of organic debris that is now lost during the process of creating a valley fill? According to the person asking the question, some in the Division of Natural Resources have felt the real loss is not so much the stream or the landform but the loss of the topsoil and the organic debris that has built up over time in the coves and valleys. He continued by noting that the DNR is looking at the possibility of collecting the material from one valley area and using that in the restoration of adjacent areas.
A: Dr. Handel commented that this debris should be mixed into the topsoil of adjacent areas and not burned. He explained that by placing the organic material back into the ground, it will rot and support the development of insects and other essential species. He expressed the opinion that it loses all its value when it is burned. Using this debris to restore a site, he continued, would be an enhancement that could be offset by a cleverly applied tax break and make improvements to having only hundreds of acres of grasslands. He stated that he has observed many sites reclaimed to grasslands when that is not typical of this region. Dr. Handel expressed the opinion that sites need to be set up to eventually return to a more natural ecosystem with much greater long-term economic value.
C: Mr. Maggard responded to Dr. Handel's closing remark with his observation that some landowners prefer the grassland because it offers more opportunity for near term economic potential.

Breakout Sessions

The symposium participants each selected to attend one of three concurrent breakout sessions to follow up on the conclusions and recommendations of the experts. These sessions were facilitated by representatives of the Department of Energy who are otherwise uninvolved with the development of the EIS. The focus of each session was to review the key conclusions and recommendations of each expert and to identify the associated benefits and potential barriers (regulatory, technical, liability, or cost) to implementing them. The experts were present in their respective breakout sessions and the Aquatic Ecosystem Enhancement Team Leader placed knowledgeable representatives of the regulatory community, particularly WVDEP and OSM, in each session. The summary presented by each facilitator to the reconvened symposium is presented below.

Aquatic Resources

Dr. Jan Wachter (National Energy Technology Laboratory), the Aquatic Resources Breakout Facilitator, presented the consensus recommendations from his breakout group to the reassembled Symposium. He noted that almost uniformly, the barriers were regulatory in nature and there were few concerns about technical, cost, or liability issues with these recommendations. Two of the recommendations developed in this breakout session were included with other breakout reports for consistency of subject matter.

1. *Make extensive use of existing sedimentation ponds and sedimentation ditches to create fisheries and wetlands thereby enhancing aquatic ecosystems on reclaimed mining sites.*

Benefits: The feasibility has been demonstrated. No major additional costs are incurred issues.

Barriers: Current regulations provide little or no consideration for aquatic ecosystem enhancement in ponds and wetlands. They are viewed primarily as a means of sediment control. Regulatory connotations inhibit long-term use. Landowners will retain long-term liability for the ponds and wetlands. Design standards for ponds and wetlands are not habitat related but are driven by storm water transport criteria. Need to have flexibility in regulations to encourage designs that consider base flow and bank full loading. In summary, there are very few incentives to develop standing water on the site, primarily due to geotechnical safety issues in SMCRA.

2. *Take advantage in the design of the valley fill for the generation and maintenance of base flow to create perennial aquatic habitat*

Benefits: Development of base flow is critical to the development and enhancement of the aquatic ecosystem. It is difficult not to have base flow (e.g., chimney drain effect) directed to the center of the hollow.

Barriers: Engineering driven regulations oppose and are frequently counterproductive to aquatic ecosystem enhancement (e.g., engineering stability goals versus aquatic enhancement goals). No incentives are given to the operator for designing stream channels and other aquatic habitat into the valley fill structure to establish base flow.

3. *Create incentives (or remove disincentives) for companies to voluntarily manage wetlands at reclamation sites.*

Benefits: Provides incentives to the operator and landowner to develop and maintain aquatic habitat.

Barriers: Regulation reform is needed with "hold harmless" consideration with respect to wetlands and other aquatic habitat, especially related to the landowner's liability if he should need to remove or fill in the wetlands.

4. *Modify overburden disposal and valley fill practices to minimize the impact on primary and secondary streams.*

Benefit: Minimizes the impact on natural streams.

Barrier: Deferred discussion of barriers to Landform breakout due to time constraints.

5. *Restore existing stream channels and flood plains where opportunities exist.*

Benefit: Minimizes the impact on natural streams.

Barrier: Also deferred discussion of barriers to Landform breakout due to time constraints.

Vegetation

Dr. Heino Beckert (National Energy Technology Laboratory), the Vegetation Breakout Facilitator, presented the following summary to the reassembled symposium. His breakout group reached consensus on six key recommendations with the associated benefits and barriers. The seventh recommendation below was developed in the Aquatic Resources Breakout Session and moved to this list for consistency of subject matter.

1. Stockpile native topsoil for use in lining banks of streams, ponds, and wetlands; also provide pre-treatment of topsoils to increase soil aeration:

Benefits: Increase of moisture retention capability of soil, facilitate infiltration of water and plant seeds; increase likelihood of successful revegetation.

Barriers: Difficulties in obtaining enough suitable topsoil; storage of topsoil may decrease its fertility by leaching and loss of microbial content.

2. Avoid use of exotic invasive plants in revegetation efforts.

Benefits: Development and maintenance of native flora, which is best suited for providing appropriate habitat for native wildlife and for erosion control.

Barriers: None; but nurseries must be encouraged to make available appropriate native plant species; this may present difficulties and increase of overall revegetation costs.

3. Plant a mix of different genotypes.

Benefits: Provides for the appropriate genetic diversity, resulting in better resistance to pathogens and will ensure healthy habitat suitable for a variety of native fauna.

Barriers: Nurseries will market what they can sell; it may be difficult to obtain a healthy genetic mix of the appropriate species instead of clones of species selected for revegetating mine sites.

4. Plant a buffer zone around streams and ponds.

Benefits: Enhancement of aquatic communities; results in ecological advantages by providing appropriate habitat for littoral flora and fauna.

Barriers: Restriction of access for cleaning ponds of sediments; possible safety concerns with pipes being damaged by tree roots.

5. Use of bio-engineering materials for use in stream channels and banks.

Benefits: Prevents erosion, stabilizes banks, enhances seed development and speeds up the overall revegetation process.

Barriers: Suitable only in moderately flat terrain; must last at least five years while vegetation becomes properly established; may require engineering approval for installation.

6. Plant ground cover to attract and keep pollinating insects.

Benefits: Promotes reproduction of planted vegetation.

Barriers: Wildflower seeds are expensive; care must also be taken that these plants do not crowd out those species planted for the actual revegetation project.

7. (From Aquatic Resources Group) Modify soil characteristics in order to restore native species. Restore the innoculum to the topsoil and allocate topsoil for riparian and ridge zones- not necessarily the entire landscape.

Benefits: Encourages the restoration of native species and diversity to the reclaimed site and provides riparian and ridge buffer zones.

Barriers: This recommendation conflicts with current topsoil regulations such as the one that provides a requirement for pH maintenance. May be counter to the decreased use by regulators of the "fish and wildlife land-use option" for non-AOC sites. Cost and education of regulators and operators are also barriers.

Landform

Mr. Randy Moore (EG&G), the Landform Breakout Facilitator, presented the consensus of his breakout group to the reconvened symposium. This breakout group identified two summary recommendations. A third recommendation below was developed in the Aquatic Resources Breakout Session and moved to this list for consistency of subject matter:

1. *Promote natural landforms on backfill areas to create more natural drainage patterns.*

NOTE: For more discussion on natural landform regrading on reclaimed areas, see the earlier discussion by Mr. Horst Schor and the relevant supporting information in the appendix. "Natural landforms" for this region of Appalachia are NOT flat top fills with a terraced face. Fills and regraded mined lands would have rounded tops with fairly smooth hill side slopes and valleys with stream channels - similar to unmined areas nearby.

Benefits: Natural landforms promote establishment of more stable and productive aquatic ecosystems in the drainage system. In some cases, the reclaimed site aquatic resources may be of greater economic value than the existing resources that were impacted by earlier land use.

Barriers: The principal barrier is the current 100-foot buffer zone imposed by Judge Haden's ruling based on the Clean Water Act, which prohibits valley fills on existing natural streams even temporarily. Additionally, landform contouring on the valley fill can extend the footprint required for disposing of the excess spoil. Longer lengths of streams can be impacted than currently allowed by the AOC model.

2. *Capture flow from down dip side of the mine site and within the valley fill to create base flow within the valley fill.*

NOTE: Water percolates down through the rocks and soils which have been placed back on the floor of the mined area. The floor of the mine is usually an aquatard which redirects the groundwater to the down dip side where it emerges as a "spring." If these "springs" are covered by valley fills in the reclamation process, they can be directed to *the toe of the fill through special channels built to carry the flow directly to the discharge point and minimize contact with fill material.*

Benefit: Capturing base flow from subsurface flow on the down dip side of the mine site provides an attractive opportunity to enhance the aquatic resources within the valley fill area.

Barrier: Capturing base flow at the outcrop of subsurface flow requires the movement of substantial spoil higher up on the backfill. Mr. Lawson demonstrated how this is possible with a dragline but could be costly at a truck and shovel operation. Any landforming to create natural relief or develop base flow, other than surface contouring, must occur during the initial movement of material while the large earthmoving equipment is still available or it may not be economically feasible. Additionally, the haul roads necessary to create the side fill will create additional compaction that is counterproductive to some post-mining land uses, such as commercial forestry.

3. (From Aquatic Resources Group) *Modify drainage systems to create stream and wetland areas on steeper regions.*

Benefit: Natural streams and wetlands in steeper regions is more characteristic of the Appalachia region. Note that there are not many wetlands in the Appalachian region that were not created by humans.

Barrier: The requirement to limit the total area of valley fills restricts the ability to construct more natural configurations. Aquatic ecosystem enhancement with natural channels may require the development of larger valley fills than allowed by the AOC model.

Symposium Conclusion

Dr. Ziemkiewicz expressed his appreciation to the group for their effort to develop the recommendations along with the benefits and barriers for further consideration during the EIS process. For his closing remarks, he provided his perspective on each of the three symposium focus areas, Vegetation, Aquatic Resources, and Landforms. He included a list of issues that must be developed further during the course of the EIS to be able to translate these recommendations into practice and such that the public will be able to understand their full benefit and costs.

On the topic of Vegetation he discussed the issues of soil reconstruction and plant community development. He noted that soil reconstruction is actually a very complicated issue; how to manage it, how to create soil, what criteria describes sufficient soil quality compared to overburden? How should reconstructed soil be handled? How long can they be stockpiled and still retain their beneficial qualities? Dr. Ziemkiewicz also discussed the issue of soil decompaction and the implications for compaction from using a dragline compared to a truck and shovel operation. He also noted the issues; is decompaction permanent? While it is necessary to reestablish vegetation, how effective is it over time? Dr. Ziemkiewicz commented that all of these questions and more will have to be addressed to communicate consistent criteria in advance to operators for the reclamation of a mine site.

Dr. Ziemkiewicz also discussed the complexity of plant community development. He asked the question, what kind of plant communities are needed at a reclamation site? Obviously, continued Dr. Ziemkiewicz, we need several different types including aquatic, riparian, and upland forests. He continued to question what species of plants should each type include? The regulation, according to Dr. Ziemkiewicz, must identify critical plant communities and essential native plant species. Another key issue he noted is that there is a need coordinate natural plant succession on mine sites while maintaining adequate erosion control because the operator cannot immediately plant oak trees or pine trees on a spoil area and hope to be successful. He concluded that we must have realistic expectations that consider natural succession to be able to coincidentally achieve erosion control while restoring natural ecosystems.

On the topic of Aquatic Resources, Dr. Ziemkiewicz asked the question, can streams be reestablished on mine spoil? From his experience, he commented, many operators have expended a lot of resources to try and place streams across spoil material without success. He continued that these reaches are difficult to maintain due to the high permeability of the mine spoil. According to Dr. Ziemkiewicz, operators and regulators have to consider the value of constructed wetlands compared to the value of the original ephemeral streams that may be covered in the process of valley fill. Furthermore, he questioned what is the comparative productivity of wetlands, ponds, and streams on mine sites? He commented that we may not be very close to getting the answers for this and other questions necessary to consider a regulatory basis for developing aquatic resources.

On the topic of Landforms he summarized the issue as the optimization of placement of fill material in a valley fill or by back hauling. Dr. Ziemkiewicz noted that we must be able to prescribe how to configure the landscape to meet all the competing criteria including aquatic ecosystem enhancement.

At the end of the EIS process, he concluded, we must be able to proclaim what we are trying to accomplish and the public must be able to understand the benefit to the aquatic ecosystem in comparison to other concerns.

AQUATIC ECOSYSTEM ENHANCEMENT AT MOUNTAINTOP MINING SITES

January 12, 2000
Holiday Inn Charleston House

Symposium Agenda

9:00	Welcome and Introductions- Paul Ziemkiewicz
9:15	Overview of First Order Watersheds - Bruce Wallace
9:45	Mine Sites Visited by the Panel Members - Courtney Black
10:00	Catenary Coal's Success Restoring Aquatic Habitat - Peter Lawson
10:15	***BREAK***
10:30	Panel Introduction - Paul Ziemkiewicz
10:45	Land Form - John Morgan & Horst Schor
11:45	***LUNCH*** *(on your own)*
12:45	Aquatic Resources - Rocky Powell, Randy Maggard, & Bruce Wallace
1:45	Vegetation - Steven Handel & Ben Faulkner
2:45	***BREAK***
3:00	Breakout sessions by theme (Grand Ballroom) to identify benefits & barriers to panelist suggestions. Regulatory experts from WVDEP & OSM will be assigned to each group.
4:00	Reconvene (Lobby Ballroom) to share major points for each theme - Theme Facilitators
4:45	Symposium Summary - Paul Ziemkiewicz
5:00	Adjourn

Participants List

Aquatic Ecosystem Enhancement at Mountaintop Mining Sites Symposium

January 12, 2000

Craig Aaron
Evergreen Mining
P.O. Box 972
Cowen, WV 26206
Phone: 304/226-2111
Fax: 304/226-5474
E-mail: caaron@aeiresources.com

Larry Abbot
Summit Engineering, Inc.
400 Allen Drive, Suite 100
Charleston, WV 25302
Phone: 304/342-1342
Fax: 304/342-1379
E-mail: labbot@summit-engr.com

Gary Acord
Cline Resources & Development
430 Harper Park Drive
Beckley, WV 25801
Phone: 304/ 255-7458
Fax: 304/255-4908
E-mail:

Larry Alt
WV DEP
10 McJunkin Road
Nitro, WV 25177
Phone: 304/759-0510
Fax: 304/759-0528
E-mail: Lalt@mail.dep.state.wv.us

Jim Ashby
Mettiki Coal, LLC
293 Table Rock Road
Oakland, MD 21550
Phone: 301/334-5336
Fax: 301/334-1602
E-mail: jashby@gcnet.net

U.K. Bachhawat
Pittston Coal Management Company
P.O. Box 11718
Charleston, WV 25339
Phone: 304/347-8200
Fax: 304/347-8980
E-mail: ubachhaw@pistonminerals.com

Terry Ball
Massey Coal Services
P.O. Box 484
Omar, WV 25638
Phone: 304/946-2421
Fax: 304/946-2404
E-mail: terry.ball@masseycoal.com

Marla Barbour
Kentucky Department of Fish and
Wildlife Resources
Arnold L. Mitchell Building
#1 Game Farm Road
Frankfort, KY 40601
Phone: 502/564-7109, x367
Fax: 502/564-4519
E-mail: marla.barbour@mail.state.ky.us

Heino Beckert
US DOE NETL
P.O. Box 880 Collins Ferry Road
Morgantown, WV 26507-0880
Phone: 304/285-4132
Fax: 304/285-4403
E-mail: heino.beckert@netl.doe.gov

Robert Bays
Arch Coal
5311 Ashbrook Road
Cross Lanes, WV 25313
Phone: 304/369-6222 x139
Fax: 304/369-0542
E-msil: bbays@archcoal.com

Les Bincent
Virginia Department of Mines, Minerals,
and Energy
P.O. Drawer 900
Big Stone Gap, VA 24219
Phone: 540/523-8159
Fax: 540/523-8163
E-mail: lsb@mme.state.va.us

Courtney Black
WVU National Mine Land Reclamation Center
202 E NRCCE
P.O. Box 6064
Morgantown, WV 26506
Phone: 304/293-2867 x5447
E-mail: dblack@wvu.edu

Brian Bolling
Charleston Daily Mail
1001 Virginia Street East
Charleston, WV 25301

Frank Borsuk
Potesta & Associates, Inc.
2400 MacCorkle Avenue, SE
Charleston, WV 25304
Phone: 304/342-1400
Fax: 304/343-9031
E-mail: faborsuk@potesta.com
faborsuk@teays.net

Darin Brown
Kimberly Industries, Inc.
One Wellford Way
Charleston, WV 25311
Phone: 304/346-3775
Fax: 304/346-3798

Earl H. Brown, Jr.
GAI Consultants, Inc.
315 70th Street, SE
Charleston, WV 25304
Phone: 304/926-8100
E-mail: gaiwv@citynet.net

Gary Bryant
U.S. EPA
1060 Chapline St.
Wheeling, WV 26003
Phone: 304/234-0230
Fax: 304/234-0257
E-mail: bryant.gary@epamail.epa.gov

R. Scott Bumsworth
GAI Consultants, Inc.
315 70th Street, SE
Charleston, WV 25304
Phone: 304/926-8100
E-mail: gaiwv@citynet.net

Carey Butler
WPI
3606 Collins Ferry Road Suite 202
Morgantown, WV 26505
Phone: 304/598-9383 x15
Fax: 304/598-9392
E-mail: carey_butler@mt.wpi.org

Jim Canterbury
Mountain State Company
P.O. Drawer O
Cedar Grove, WV 25039
Phone: 304/949-4762
Fax: 304/949-4764
E-mail:

Steven Case
Coal Mac, Inc.
P.O. Box 3428
Pikeville, KY 41502
Phone: 606/432-0171
Fax: 606/437-4213
E-mail: SLCase@EastKy.net

Doug Chambers
USGS - WRD
11 Dunbar St.
Charleston, WV 25301
Phone: 304/347-5130
Fax: 304/347-5133
E-mail: dbchambe@usgs.gov

Mary Channel
WV Division of Environmental Protection
116 Industrial Drive
Oak Hill, WV 25901
Phone: 304/465-1911
Fax: 304/465-0031
E-mail: mchannel@mail.dep.state.wv.us

George Chappel
Summit Engineering, Inc.
400 Allen Drive, Suite 100
Charleston, WV 25302
Phone: 304/342-1342
Fax: 304/342-1379
E-mail: gchappel@summit-engr.com

Casey Clapsaddle
U.S. Fish and Wildlife Service
Suite 322
315 S Allen Street
State College, PA 16801
Phone: 814/234-4090
Fax: 814/234-0748
E-mail: casey_clapsaddle@fws.gov

Debbie Collinsworth
EcoSource, Inc
112 Dennis Drive
Lexington, KY 40503
Phone: 606/277-8686
Fax: 606/277-8686
E-mail: ecosourtce@hotmail.com

James W. Copley, Jr.
Coastal Coal-West Virginia, LLC
Brooks Run Operation
61 Missouri Run Road
Cowen, WV 26206
Phone: 304/226-5391

Danny Cox
Massey Coal Services, Inc.
P.O. Box 1951
Charleston, WV 25327
Phone: 304/345-3556
Fax: 304/345-3623
E-mail: danny.cox@masseycoal.com

Richard Darnell
WVDEP -AML&P
10 McJunkin Road
Nitro, WV 25071
Phone: 304/ 759-0521
Fax: 304/759-0527

Ron Damron
Piston Coal Management Company
P.O. Box 11718
Charleston, WV 25339
Phone: 304/347-8200
Fax: 304/347-8980
E-mail: rdamron@pistonminerals.com

David Densmore
U.S. Fish and Wildlife Service
Suite 322
315 S Allen Street
State College, PA 16801
Phone: 814/234-4090
Fax: 814/234-0748
E-mail: david_densmore@fws.gov

Kent DesRocher
Arch of WV
P.O. Box 1 HC 614, Box 156
Yolyn, WV 25654
Phone: 304/369-6222, ext. 134
304/792-8200
Fax: 304/369-0542
304/792-8260
E-mail: kdesrocher@archcoal.com

Lori W. Dials
Kentucky Department of Fish and Wildlife Resources
Arnold L. Mitchell Building
#1 Game Farm Road
Frankfort, KY 40601
Phone: 502/564-7109, x375
Fax: 502/564-4519
E-mail: lori.dials@mail.state.ky.us

Barry Doss
AEI Resources
P.O. Box 489
Cabin Creek, WV 25035
Phone: 304/595-3330
Fax: 304/595-3301
E-mail: bdoss@aeiresources.com

Joe Dotson
Massey Coal Services
P.O. Box 484
Omar, WV 25638
Phone: 304/946-2421
Fax: 304/946-2404

John L. Dovak
Kentucky Division of Water
14 Reilly Road
Frankfort, KY 40601
Phone: 502/564-3410
Fax: 502/564-0111
E-mail: sampson@nrdep.nr.state.ky.us

Roger Dunlap
Kimberly Industries, Inc.
One Wellford Way
Charleston, WV 25311
Phone: 304/346-3775
Fax: 304/346-3798

J. D. Elkins
Summit Engineering, Inc.
203 Main Avenue
Logan, WV 25601
Phone: 304/752-5038
Fax: 304/752-5039
E-mail: jelkins@summit-engr.com

Larry Emerson
Arch Coal, Inc.
P.O. Box 6300
Huntington, WV 25771
Phone: 304/526-3581
Fax: 304/526-3680
E-mail: lemerson@archcoal.com

Erkan Esmer
Esmer Associates, Inc.
P.O. Box 426
Boomer, WV 25031
Phone: 304/779-2131
Fax: 304/779-2859
E-mail: esmer@intelos.net

Ben Faulkner
Bratton Farm
171 Willowbrook Road
Princeton, WV 24740
Phone: 304/487-2886
Fax: 304/425-3727
E-mail: bratfarm@pol.net

James Felby
Catenary Coal Company
251 Frame Road
Elkview, WV 25071
Phone: 304/595-7233
Fax: 304/595-4063

Kermit Fincham, Jr.
Progress Coal
HC 78
P.O. Box 1796
Madison, WV 25130
Phone: 304/369-9101
Fax: 304/369-9105
E-mail: kermit.fincham@masseycoal.com

Michael A. Fioravante
GAI Consultants, Inc.
315 70th Street, SE
Charleston, WV 25304
Phone: 304/926-8100
E-mail: gaiwv@citynet.net

David Fisher
Sturm Environmental Services
P.O. Box 650
Bridgeport, WV 26330
Phone: 304/623-6549
Fax: 304/623-6552
E-mail: ses@iolinc.net

Blair Gardner
Arch Coal, Inc.
City Place One
St. Louis, MO 63141
Phone: 314/994-2725
Fax: 314/994-2734
E-mail: bgardner@archcoal.com

Anthony Gatens
Arch of WV
HC 61, Box 156
Yolyn, WV 25654
Phone: 304/792-8253
Fax: 304/792-8260
E-mail: agatens@archcoal.com

Bryce D. Good
GAI Consultants, Inc.
315 70th Street, SE
Charleston, WV 25304
Phone: 304/926-8100
E-mail: gaiwv@citynet.net

T.J. Gregorsky
Fola Coal Company
P.O. Box 180
Bickmore, WV 25019
Phone: 304/587-4100
Fax: 304/587-2469
E-mail: wvsailor@fola.wv.net

David Gruber
Biological Monitoring, Inc.
1800 Kraft Drive Suite 101
Blacksburg, VA 24060
Phone: 540/953-2821
Fax: 540/951-1481
E-mail: bmi@biomon.com

Jack Hagewood
Pittston Coal
P.O. Boc 11718
Charleston, WV 25339
Phone: 304/587-4777 x33
E-mail: JHagewood@pittstonminerals.com

Steven Handel
Department of Ecology, Evolution, and Natural Resources
Rutgers University
1 College Farm Road
New Brunswick, NJ 08901-1582
Phone: 732/932-4516
E-mail: handel@aesop.rutgers.edu

Rebecca Hanmer
U.S. Environmental Protection Agency
4505 F Street
Washington, DC 20460
Phone: 202/260-4470
Fax: 202/401-5341
E-mail: hanmer.rebecca@epa.gov

Jimmy Harless
Hampden Coal
P.O. Box 1389
Gilbert, WV 25601
Phone: 304/664-2960
Fax: 304/664-2962

Leith Hartman
Pritchard Mining
184 1/2 Summers St.
Charleston, WV 25301
Phone: 304/346-2268
E-mail: rlh3@citynet.net

David Hartos
OSM
3 Parkway Center
Pittsburgh, PA 15220
Phone: 412/937-2909
Fax: 412/937-3102
E-mail: dhartos@osmre.gov

Gary Hatfield
Rawl Sales
Box 722
Matewan, WV 25678
Phone: 304/235-4290
Fax: 304/235-3034
E-mail: gary.hatfield@masseycoal.com

David Hibbs
Cummins Cumberland, Inc.
5304 Ashbrook Road
Cross Lanes, WV 25313
Phone: 304/776-5376
E-mail: drhibbs@ibm.net

Nancy Hieb
WV Division of Environmental Protection
116 Industrial Drive
Oak Hill, WV 25901
Phone: 304/465-1911
Fax: 304/465-0031
E-mail: nhieb@mail.dep.state.wv.us

Cliff Higgerson
Hobet Mining
P.O. Box 305
Madison, WV 25130
Phone: 304/369-8126
E-mail: chiggerson@archcoal.com

J.D. Higginbotham
Bluestone Coal Corporation
P.O. Box 1085
Beckley, WV 25801
Phone: 304/252-8528
Fax: 304/255-6106
E-mail: jdhjr@bluestoneindustries.com

Tiff Hilton
WOPEC
RR2 Box 294B
Lewisburg, WV 24901
Phone: 304/645-7633
Fax: 304/645-4985
E-mail: WOPEC@newwave.net

Ken Hodak
Arch of WV
P.O. Box 1 HC 614, Box 156
Yolyn, WV 25654
Phone: 304/792-8200
Fax: 304/792-8260
E-mail: khodak@archcoal.com

Michael Hoeft
WV Division of Natural Resources
Route 1, Box 484
Point Pleasant, WV 25550
Phone: 304/675-0871
Fax: 304/675-0872
E-mail: hoeftm@mail.wvnet.edu

William Hoffman
U.S. Environmental Protection Agency
1650 Arch Street
Philadelphia, PA 19104
Phone: 215/814-2787
E-mail: hoffman.william@epamail.epa.gov

Teresa Hughes
US. Army Corps of Engineers
502 8th Street
Huntington, WV 25701
Phone: 304/529-5710
Fax: 304/529-5085
E-mail:
Teresa.D.Hughes@Lrh01.usace.army.mil

Mike Isabell
Fola Coal Company
P.O. Box 180
Bickmore, WV 25019
Phone: 304/587-4100
Fax: 304/587-2469
E-mail: wvsailor@fola.wv.net

Scotty Ison
P&A Engineers
P.O. Box 470
Alum Creek, WV 25003
Phone: 304/756-4066
Fax: 304/756-4068
E-mail: pandawv@newwave.com

Ken Job
Marrowbone Development Co.
P.O. Box 119
Naugatuck, WV 25685
Phone: 304/393-3736

Jamie Johnson
Arch Coal, Inc.
P.O. Box 305
Madison, WV 25130
Phone: 304/369-6222
Fax: 304/369-6829
E-mail: jajohnson@archcoal.com

Randy Kelley
WV Division of Natural Resources
525 Tiller Street
Logan, WV 25601
Phone: 304/792-7075
Fax: 304/792-7078
E-mail: kellyr@mail.wvnet.edu

Robert Kenny
Triangle Survey
One Valley Square Suite 970
Charleston, WV 25301
Phone: 304/342-4989

Robert Kiser
Appalachian Technical Services
P.O. Box 98
Whitesburg, KY 41858
Phone: 606/633-0613
Fax: 606/633-0616

Eugene Kitts
Summit Engineering, Inc.
400 Allen Drive, Suite 100
Charleston, WV 25302
Phone: 304/342-1342
Fax: 304/342-1379
E-mail: gkitts@summit-engr.com

Allen Klein
U.S. Department of the Interior
Office of Surface Mining
3 Parkway Center
Pittsburgh, PA 15220
Phone: 412/937-2828
Fax: 412/937-2903
E-mail: aklein@osmre.gov

Keith Krantz
WV DNR
Rt 1, Box 484
Pt. Pleasant, WV 25504
Phone: 304/ 675-0871

Peter Lawson
Catenary Coal
5914 Cabin Creek Road
Eskdale, WV 25075
Phone: 304/595-4036
Fax: 304/595-4063
E-mail: plawson@archcoal.com

Penny Loeb
11234 Richard Grove Drive
Great Falls, VA 22066
Phone: 703/430-3451
Fax:
E-mail: cfdodge@msa.com

Mike Mace
WV Division of Environmental Protection
No. 10 McJunkin Road
Nitro, WV 25143
Phone: 304/759-0595
Fax: 304/759-0587
E-mail: mmace@mail.dep.state.wv.us

Paul Maggard
Appalachian Technicla Services
P.O. Box 98
Whitesburg, KY 41858
Phone: 606/633-0613
Fax: 606/633-0616
E-mail: atsincky@kih.net

Randy Maggard
PenCoal
P.O. Box 191
Dunlow, WV 25511
Phone: 304/385-4951
E-mail: randy_maggard@pencoal.com

Robert Marsh
Pen Coal Corp
P.O. Box 191
Dunbar, WV 25511
Phone: 304/385-4950
Fax: 304/385-4594
E-mail: Robert_Marsh@pencoal.com

Bob Martin
P&A Engineers
P.O. Box 279
Louisa, KY 41230
Phone: 606/673-4413
Fax: 606/673-4415
E-mail: pandaky@foothills.net

David L. Martin
Coastal Coal-West Virginia, LLC
Brooks Run Operation
61 Missouri Run Road
Cowen, WV 26206
Phone: 304/226-5391

Larry Mauk
Hampden Coal
P.O. Box 1389
Gilbert, WV 25601
Phone: 304/664-2960
Fax: 304/664-2962

Bernard Maynard
Office of Surface Mining
Building No. 3
Parkway Center Complex
Pittsburgh, PA 15220
Phone: 412/937-2873
Fax: 412/937-3012
E-mail: bmaynard@osm.gov

Cindy Maynard
WV DEP
No. 10, McJunkin Road
Nitro, WV 25143
Phone: 304/759-0570
Fax: 304/759-0527
E-mail: cmaynard@mail.dep.state.wv.us

Raymond Maynard
White Flame Energy
Box 379
Red Jacket, WV 25692
Phone: 304/426-6090

Ron McAhron
Cannelton Coal
P.O. Box 150
Cannelton, WV 25036
Phone: 304/442-5106
Fax: 304/442-9451
E-mail: rmcahron@aeiresources.com

John McDaniel
Arch Coal, Inc.
P.O. Box 305
Madison, WV 25130
Phone: 304/369-6222
Fax: 304/369-6829
E-mail: jmcdaniel@archcoal.com

John McNew
White Flame Energy
P.O. Box 343
Red Jacket, WV 25692
Phone: 304/426-6090
Fax: 304/426-4231
E-mail: iam4wv@cwv.net

Scott McPhilliamy
U.S. Environmental Protection Agency
1060 Chapline Street
Wheeling, WV 26003-2995
Phone: 304/234-0233
Fax: 304/234-0257
E-mail: mcphilliamy.scott@epamail.epa.gov

Chuck Meadows
P&A Engineers
P.O. Box 279
Louisa, KY 41230
Phone: 606/673-4413
Fax: 606/673-4415
E-mail: pandaky@foothills.net

Terry Messinger
U. S. Geological Survey
11 Dunbar St.
Charleston, WV 25301
Phone: 304/347-5130 x270
Fax: 304/347-5133
E-mail: tmessing@usgs.gov

Ron Miller
P&A Engineers
P.O. Box 279
Louisa, KY 41230
Phone: 606/673-4413
Fax: 606/673-4415
E-mail: pandaky@foothills.net

Earl Moles
Arch Coal, Inc.
5914 Cabin Creek Road
Eskdale, WV 25075
Phone: 304/595-7259
Fax: 304/595-4063
E-mail: emoles@archcoal.com

Dawn Moore
U. S. Geological Survey
11 Dunbar St.
Charleston, WV 25301
Phone: 304/347-5130 x285
Fax: 304/347-5133
E-mail: damoore@usgs.gov

Randy Moore
EG&G M/S O03
P.O. Box 880 Collins Ferry Road
Morgantown, WV 26507-0880
Phone: 304/285-4606
Fax: 304/285-4200
E-mail: randy.moore@netl.doe.gov

John Morgan
Morgan Worldwide Mining Consultants
P.O. Box 888
Lexington, KY 40588
Phone: 606/259-0959
E-mail: mwmc@aol.com

Rick Morgan
Hobet Mining
P.O. Box 305
Madison, WV 25130
Phone: 304/369-8126
E-mail: rmorgan@archcoal.com

Ginger Mullins
U.S. Army Corps of Engineers
502 8th St.
Huntington, WV 25701
Phone: 304/529-5710
Fax: 304/529-5085
E-mail: gingerm@lrh.usace.army.mil

Mike Murphy
Hampden Coal
P.O. Box 1389
Gilbert, WV 25601
Phone: 304/664-2960
Fax: 304/664-2962

Pat Murphy
Summit Engineering, Inc.
203 Main Avenue
Logan, WV 25601
Phone: 304/752-5038
Fax: 304/752-5039
E-mail: pmurphy@summit-engr.com

Joseph B. Myers
Coastal Coal-West Virginia, LLC
Brooks Run Operation
61 Missouri Run Road
Cowen, WV 26206
Phone: 304/226-5391

Randall Myers
Randall Myers Land Surveyors
255 Caney Valley Road
Markleysburg, PA 15459
Phone: 724/329-4994
Fax: 724/329-4994

Pam Nixon
WV Department of Environmental Protection
No. 10, McJunkin Road
Nitro, WV 25143
Phone: 304/759-0570
Fax: 304/759-0527
E-mail: pnixon@mail.dep.state.wv.us

Brian Osborn
Mepco, Inc.
P.O. Box 1209
Morgantown, WV 26507
Phone: 304/328-5757
Fax: 304/328-5743
E-mail: mepcoeng@access.mountain.net

Rocky Parsons
WVDEP
105 S. Railroad St.
Philippi, WV 26416
Phone: 304/457-3219
Fax: 304/457-5613

Katherine Paybins
USGS-WRD
11 Dunbar St.
Charleston, WV 25301
Phone: 304/347-5130
Fax: 304/347-5133
E-mail: kpaybins@usgs.gov

Bob Penn
OSM
Box 116 1941 Neely Road
Big Stone Gap, VA 24219
Phone: 540/523-0001
Fax: 540/523-4303
E-mail: RPenn@osmre.gov

Gary Persinger
Penn Virginia Coal Co.
Suite 100, One Cabin Center
Chesapeake, WV 25315
Phone: 304/949-5630
Fax: 304/949-6090

Dennis Phipps
Summit Engineering, Inc.
203 Main Avenue
Logan, WV 25601
Phone: 304/752-5038
Fax: 304/752-5039
E-mail: dphipps@summit-engr.com

Dale Pike
CONSOL Inc.
1800 Washington Road
Pittsburgh, PA 15241
Phone: 412/831-4524
Fax: 412/831-4513

Rocky Powell
Clear Creek Consulting
1317 Knopp Road
Jarrettsville, MD 21084
Phone: 410/692-2164
E-mail: rockypowell@msn.com

Ken Politan
WVDEP
10 McJunkin Road
Nitro, WV 25177
Phone: 304/759-0510
Fax: 304/759-0528
E-mail: kpolitan@mail.dep.sate.wv.us

Terry Potter
Coal Mac, Inc.
P.O. Box 3428
Pikeville, KY 41502
Phone: 606/432-0171
Fax: 606/437-4213
E-mail: tpotter@archcoal.com

David Rasnick
Summit Engineering, Inc.
101 Summit Drive
Pikeville, KY 41501
Phone: 606/432-1447
Fax: 606/432-1440
E-mail: drasnick@summit-engr.com

Jim Ratcliff
Summit Engineering, Inc.
400 Allen Drive, Suite 100
Charleston, WV 25302
Phone: 304/342-1342
Fax: 304/342-1379
E-mail: jratcliff@summit-engr.com

Chad Reed
Summit Engineering, Inc.
400 Allen Drive, Suite 100
Charleston, WV 25302
Phone: 304/342-1342
Fax: 304/342-1379
E-mail: creed@summit-engr.com

David Rider
U.S. Environmental Protection Agency
1650 Arch Street
Philadelphia, PA 19104
Phone: 215/814-2787
E-mail: rider.david@epamail.epa.gov

Jeff Robinson
Summit Engineering, Inc.
101 Summit Drive
Pikeville, KY 41501
Phone: 606/432-1447
Fax: 606/432-1440
E-mail: jrobinson@summit-engr.com

Mike Robinson
OSM
3 Parkway Center
Pittsburgh, PA 15220
Phone: 412/937-2882
Fax: 412/937-3012
E-mail: mrobinso@osmre.gov

Ron Robinson
Virginia Department of Mines, Minerals,
and Energy
P.O. Drawer 900
Big Stone Gap, VA 24219
Phone: 540/523-8159
Fax: 540/523-8163
E-mail: rdr@mme.state.va.us

Frank Rose
Piston Coal Management Company
P.O. Box 11718
Charleston, WV 25339
Phone: 304/347-8200
Fax: 304/347-8980
E-mail: frose@pistonminerals.com

Bill Sampson
Kentucky Division of Water
14 Reilly Road
Frankfort, KY 40601
Phone: 502/564-3410
Fax: 502/564-0111
E-mail: sampson@nrdep.nr.state.ky.us

Horst Schor
H.J. Schor Consulting
626 N. Pioneer Dr.
Anahiem, CA 92805
Phone: 714/778-3767
Fax: 714/778-1656
E-mail: hjschor@jps.net

Tom Serenko
Summit Engineering, Inc.
101 Summit Drive
Pikeville, KY 41501
Phone: 606/432-1447
Fax: 606/432-1440
E-mail: tserenko@summit-engr.com

Jim Serfis
EPA
515 N. Jackson St.
Arlington, VA 22201
Phone: 202/564-7161
E-mail: serfis.jim@epa.gov

Gary Sharp
WV Division of Natural Resources
Wildlife Section
Route 1, Box 484
Point Pleasant, WV 25550
Phone: 304/675-0871
Fax: 304/675-0872

Guy Shelledy
Fola Coal Company
P.O. Box 180
Bickmore, WV 25019
Phone: 304/587-4100
Fax: 304/587-2469
E-mail: wvsailor@fola.wv.net

Jeff Skousen
West Virgina University
1106 Agricultural Sciences
Morgantown, WV 26506-6108
Phone: 304/293-6256
Fax: 304/293-2960
E-mail: jskousen@wvu.edu

Eric Somerville
U.S. EPA, Region 4
Wetlands Section
61 Forsyth Street, SW
Atlanta, GA 30303
Phone: 404/562-9414
Fax: 404/562-9343
E-mail: somerville.eric@epa.gov

Keith Spears
Summit Engineering, Inc.
101 Summit Drive
Pikeville, KY 41501
Phone: 606/432-1447
Fax: 606/432-1440
E-mail: kspears@summit-engr.com

Vivian Stockman
Ohio Valley Environmental Coalition
249 Millstone Run
Spencer, WV 25276
Phone: 304/927-3265
Fax: 304/927-3265
E-mail: vivian@wvadventures.net

Jennifer Stump
Gannett Fleming Inc.
207 Senate Ave,
Camp Hill, PA 17011
Phone: 717/763-7211 x 2885
Fax: 717/763-7323
E-mail: jstump@gfnet.com

Dan Sweeney
EPA
1650 Arch St.
Philadelphia, PA 19013
Phone: 215/814-5731
Fax: 215/814-2301
E-mail: sweeney.dan@epa.gov

Aaron Taylor
Kimberly Industries, Inc.
One Wellford Way
Charleston, WV 25311
Phone: 304/346-3775
Fax: 304/346-3798

Pat Taylor
Summit Engineering, Inc.
400 Allen Drive, Suite 100
Charleston, WV 25302
Phone: 304/342-1342
Fax: 304/342-1379
E-mail: ptaylor@summit-engr.com

Cindy Tibbott
U.S. Fish and Wildlife Service
Suite 322
315 S Allen Street
State College, PA 16801
Phone: 814/234-4090
Fax: 814/234-0748
E-mail: cindy_tibbott@fws.gov

Gary D. Tinnel
Coastal Coal-West Virginia, LLC
Brooks Run Operation
61 Missouri Run Road
Cowen, WV 26206
Phone: 304/226-5391

Zac Totten
Summit Engineering, Inc.
400 Allen Drive, Suite 100
Charleston, WV 25302
Phone: 304/342-1342
Fax: 304/342-1379
E-mail: ztotten@summit-engr.com

Rena Turner
Piston Coal Management Company
P.O. Box 11718
Charleston, WV 25339
Phone: 304/347-8200
Fax: 304/347-8980
E-mail: rturner@pistonminerals.com

Dave Vande Linde
WVDEP
10 McJunkin Road
Nitro WV 25143
Phone: 304/759-0510
Fax: 304/759-0528
E-mail: dvandelinde@mail.dep.state.wv.us

Marvin Vernatter
Kimberly Industries, Inc.
One Wellford Way
Charleston, WV 25311
Phone: 304/346-3775
Fax: 304/346-3798

Sandy Vilar
WPI
3606 Collins Ferry Road Suite 202
Morgantown, WV 26505
Phone: 304/598-9383 x10
Fax: 304/598-9392
E-mail: sandy_vilar@mt.wpi.org

Mike Vines
White Flame Energy
P.O. Box 343
Red Jacket, WV 25692
Phone: 304/ 426-5405
Fax: 304/426-5406
E-mail: wvcoalboss@yahoo.com

Jan Wachter
US DOE NETL
P.O. Box 880 Collins Ferry Road
Morgantown, WV 26507-0880
Phone: 304/285-4607
Fax: 304/285-4403
E-mail: jan.wachter@netl.doe.gov

Kevin Wall
Western Pocahontas Properties
P.O. Box 2827
Huntington, WV 25727
Phone: 304/522-5757
Fax: 304/522-5401
E-mail: kwall@wpplp.com

Bruce Wallace
Department of Entomology
University of Georgia
413 Biological Sciences Building
Athens, GA 30602-2603
Phone: 706/542-7886
Fax: 706/542-2279
E-mail: wallace@sparc.ecology.uga.edu

Kevin Whipkey
Cline Resource & Development Co.
430 Harper Park Dr.
Beckley, WV 25801
Phone: 304/255-7458
Fax: 304/255-4908
E-mail: rkwhipkey@teays.net

Mark White
Arch of WV
P.O. Box 1 H 614, Box 156
Yolyn, WV 25654
Phone: 304/369-6222, ext. 138
304/792-8200
Fax: 304/369-0542
304/792-8260
E-mail: mwhite@archcoal.com

Darcy White
WV Division of Environmental Protection
No. 10 McJunkin Road
Nitro, WV 25143
Phone: 304/759-0595
Fax: 304/759-0587
E-mail: dwhite@mail.dep.state.wv.us

Darren Whitlock
Summit Engineering, Inc.
400 Allen Drive, Suite 100
Charleston, WV 25302
Phone: 304/342-1342
Fax: 304/342-1379
E-mail: dwhitlock@summit-engr.com

Ronald A. Wigal
Canaan Valley Institute
P.O. Box 673
Danis, WV 26260
Phone: 304/866-4739
Fax: 304/866-4759
E-mail: rwigal@mail.canaanvi.org

Andy Willis
Mining Consulting Services, Inc.
P.O. Box 207
Kimper, KY 41539
Phone: 606/835-3009
Fax: 606/835-3011
E-mail: awillis@miningusa.com

Allen Wood
WVDEP/AML
116 Industrial Drive
Oak Hill, WV 25801
Phone: 304/465-1911

Eddie Workman
Southern Land Company
300 Capitol Street
Suite 1401
Charleston, WV 25301
Phone: 304/346-3661
Fax: 304/346-3630

Mark S. Workman
Coastal Coal-West Virginia, LLC
Brooks Run Operation
61 Missouri Run Road
Cowen, WV 26206
Phone: 304/226-5391

Matt Workman
P&A Engineers
P.O. Box 279
Louisa, KY 41230
Phone: 606/673-4413
Fax: 606/673-4415
E-mail: pandaky@foothills.net

Dale Wright
Bluestone Coal Corporation
P.O. Box 1085
Beckley, WV 25801
Phone: 304/252-8528
Fax: 304/255-6106
E-mail: dwright@bluestoneindustries.com

Steve Young
145 Stricker Road
Charleston, WV 25314
Phone: 304/343-9369
Fax: 304/343-9369

Paul Ziemkiewicz
WVU National Mine Land Reclamation Center
P.O. Box 6064
Morgantown, WV 26505
Phone: 304/293-2867
E-mail: pziemkie@wvu.edu

Aquatic Resources on Mining Sites Tour

D. Courtney Black

National Mine Land Reclamation

West Virginia University

Photographic credit: Heino Beckert, Ph.D.

U.S. DOE, National Energy Technology Laboratory
Morgantown, WV

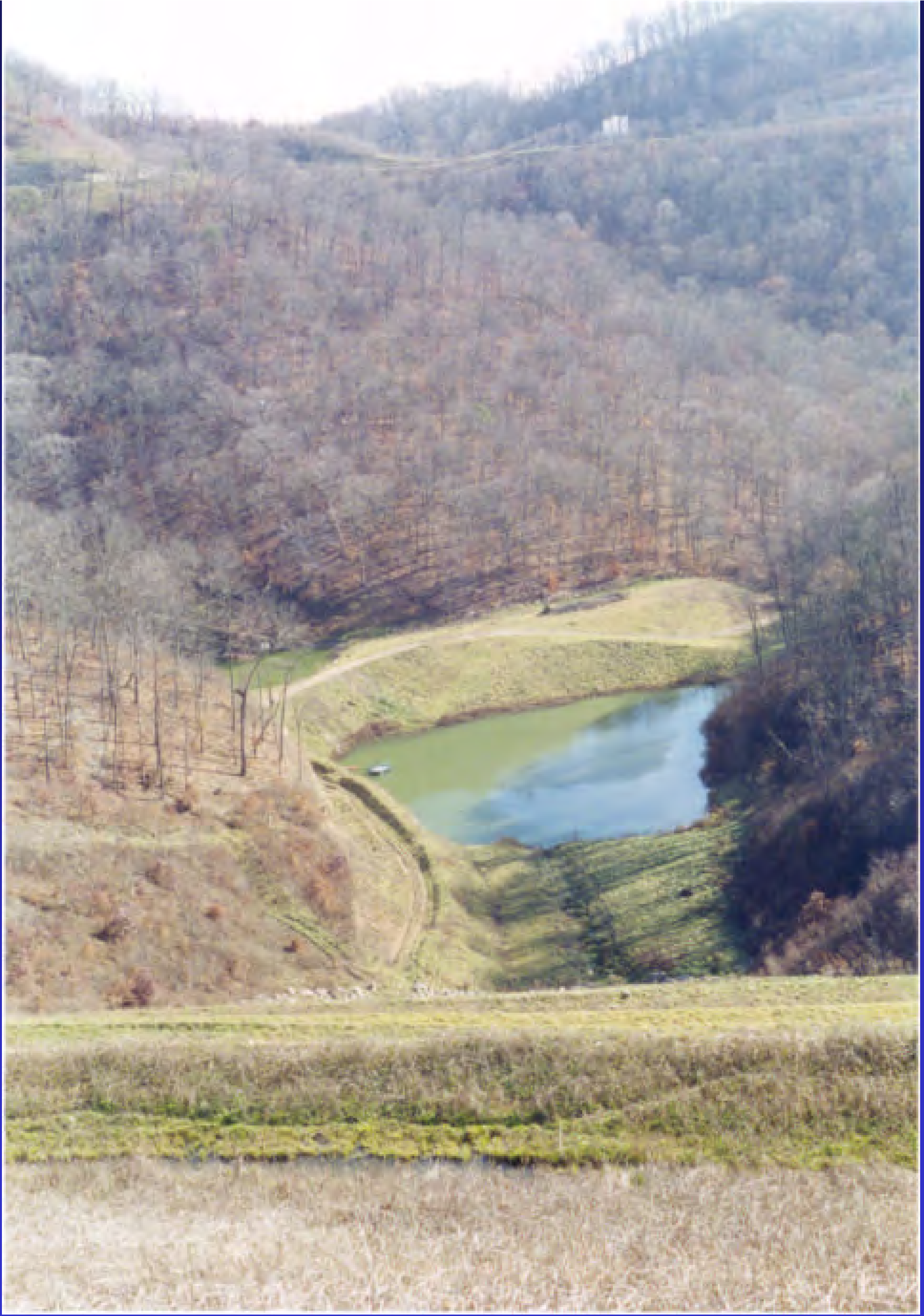
Four Mine Sites

- Elk Run Mine operated by Massey Coal Services
- Samples Mine operated by Catenary Coal
- Wayne County operations of Pen Coal Company
- Hobet Mining #21 – subsidiary of Arch Coal, Inc.

Active pit at Elk Run

# of valley fill

View of pond below valley fill



Valley Fill # 3
in construction

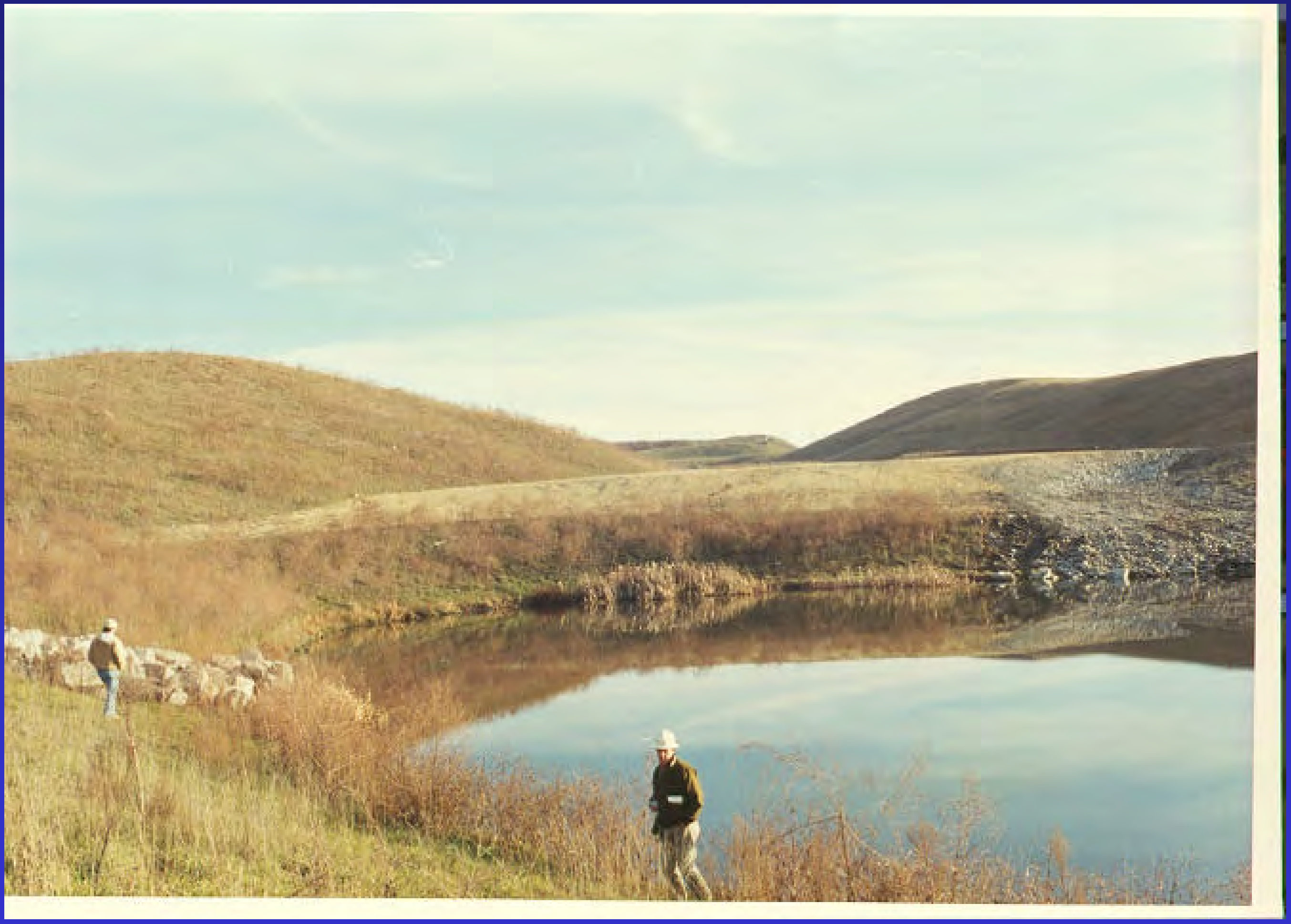
Ponds at toe of VF #3

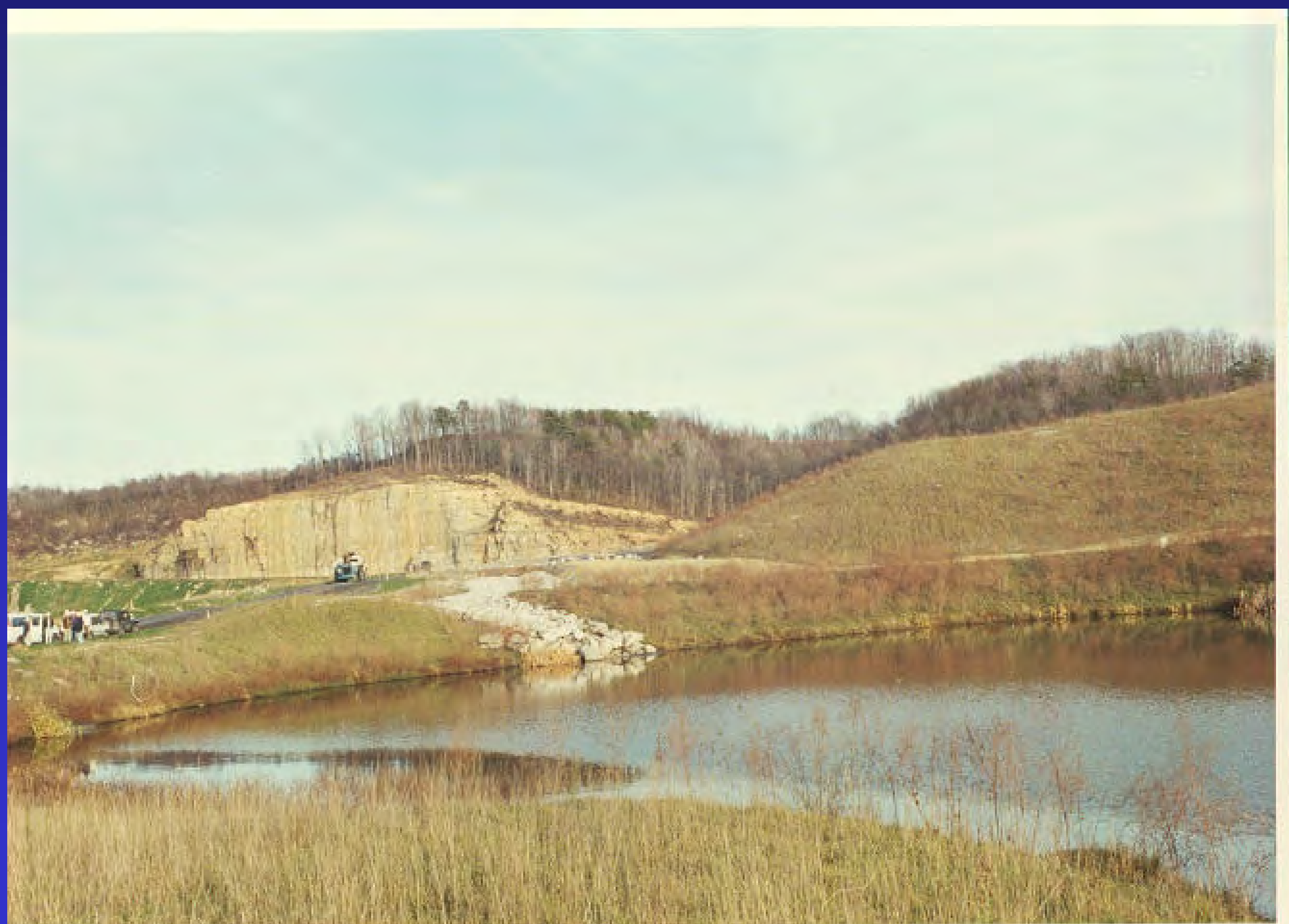
Elk Run Mine

slope has not been compacted, trees have been planted

Samples Mine

In-stream ponds below 32 acre fill area; good fish populations





Pen Coal
Encapsulation cell for toxic material

Combination Ditch

constructed on 8 month old reclamation for sediment and storm water control

Rollem Fork Surface Mine

Combination Ditch

Rollem Fork Valley Fill

Contoured Valley Fill

Tree planting on 8 year old reclamation – Frank Branch

Hobet Mining #21
20 year old valley fill

10 year old reclamation

Rolling landscape created by dragline; valley fill in center

in center, valley fill on left

Close up of combination ditch

Reclaimed landscape at Hobet #21

Aquatic Ecosystem Enhancements At A Mountaintop Mining Site

Presented January 12, 2000
Charleston, West Virginia

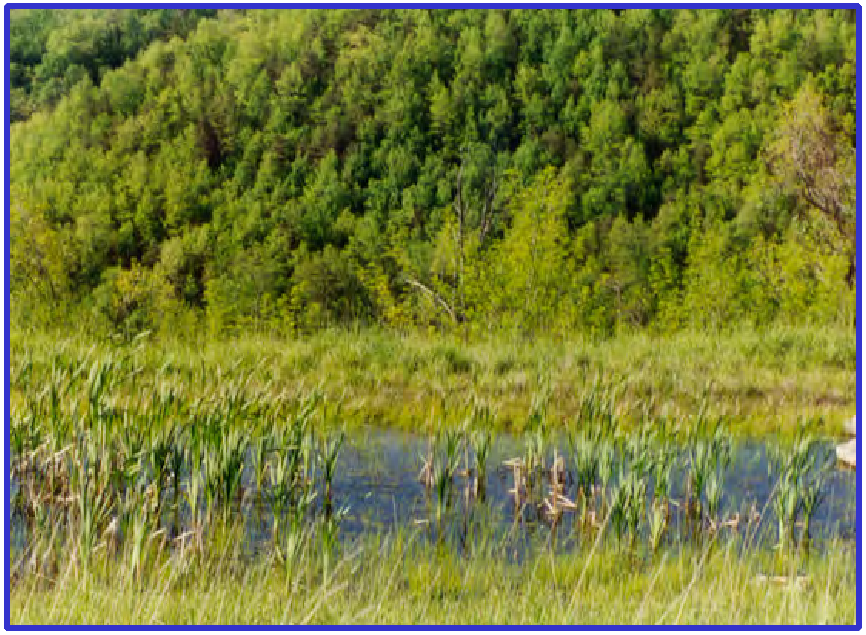
Coal Catenary

Aquatic Ecosystem Enhancement At A Mountaintop Mining Site

- Background / Scope of Samples Mine Project
- Structures constructed as conditions of permits
  - In-stream ponds
  - On bench structures
- Aquatic Ecosystem Enhancement Projects
  - G-Ponds
  - Abandoned Mine Land Projects
- Landform Restoration

Aquatic Ecosystems Constructed as Conditions of Permits

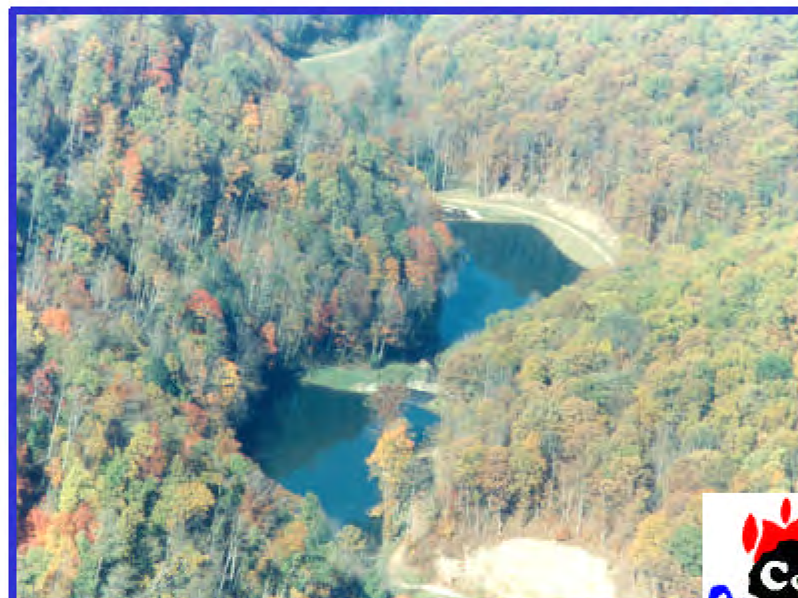
In-stream Ponds



On Bench Structures

Examples of in-stream ponds...



Coal Catenary

Examples of on bench structures...




Aquatic Ecosystem Enhancement...

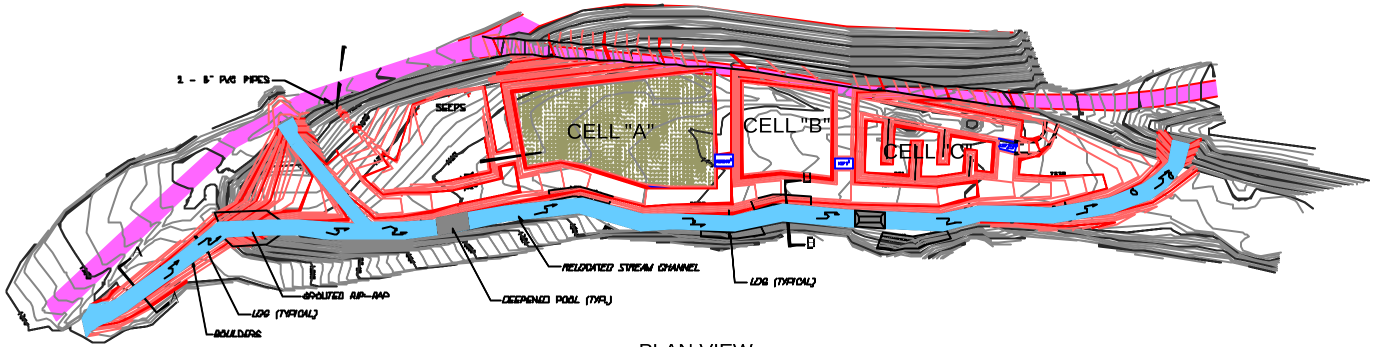
COAL CATENARY

COAL CATENARY

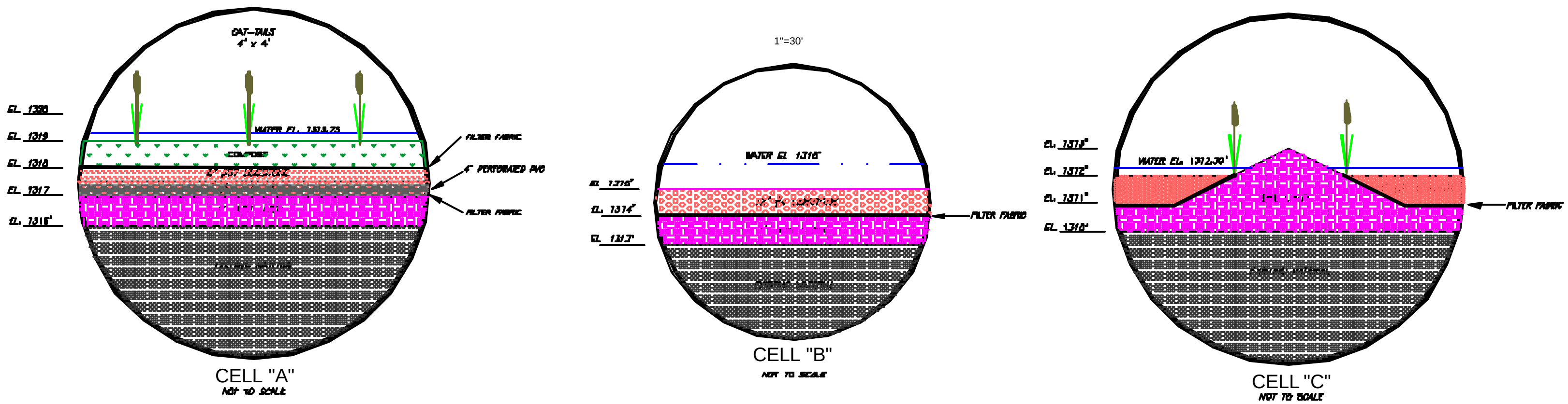
Abandoned Mine Lands Projects...

Areas of Pre- Law Mining

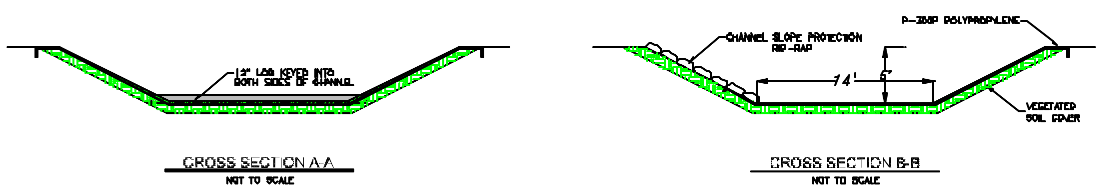
Engineering Design of Wetlands...



PLAN VIEW
1"=50'



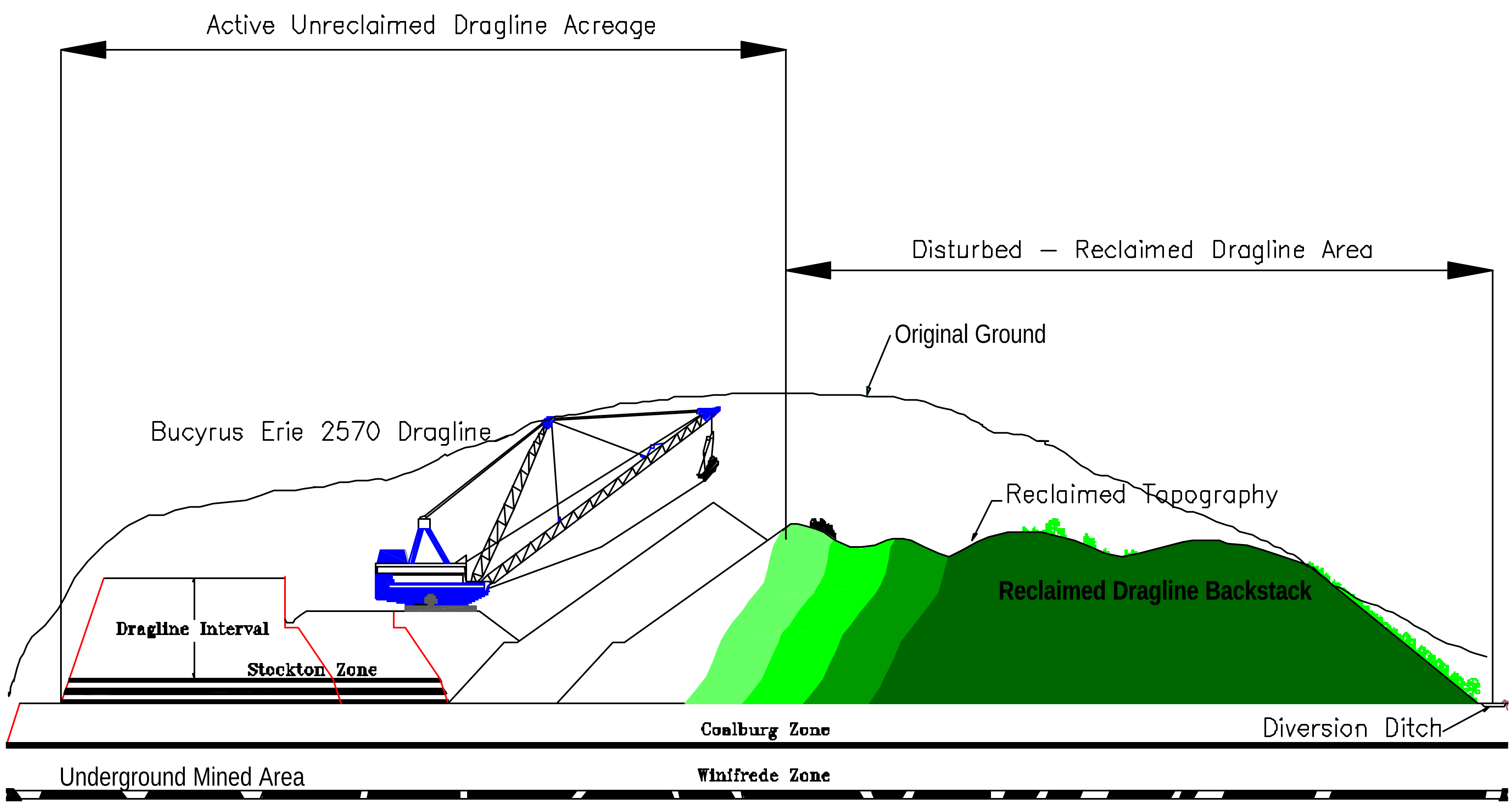
WETLANDS DETAILS



STREAM CHANNEL SECTIONS


Construction of Wetlands


Land Forms Restoration...



During Mining

Reclaimed Area

Reclaimed Area

Reclaimed Area

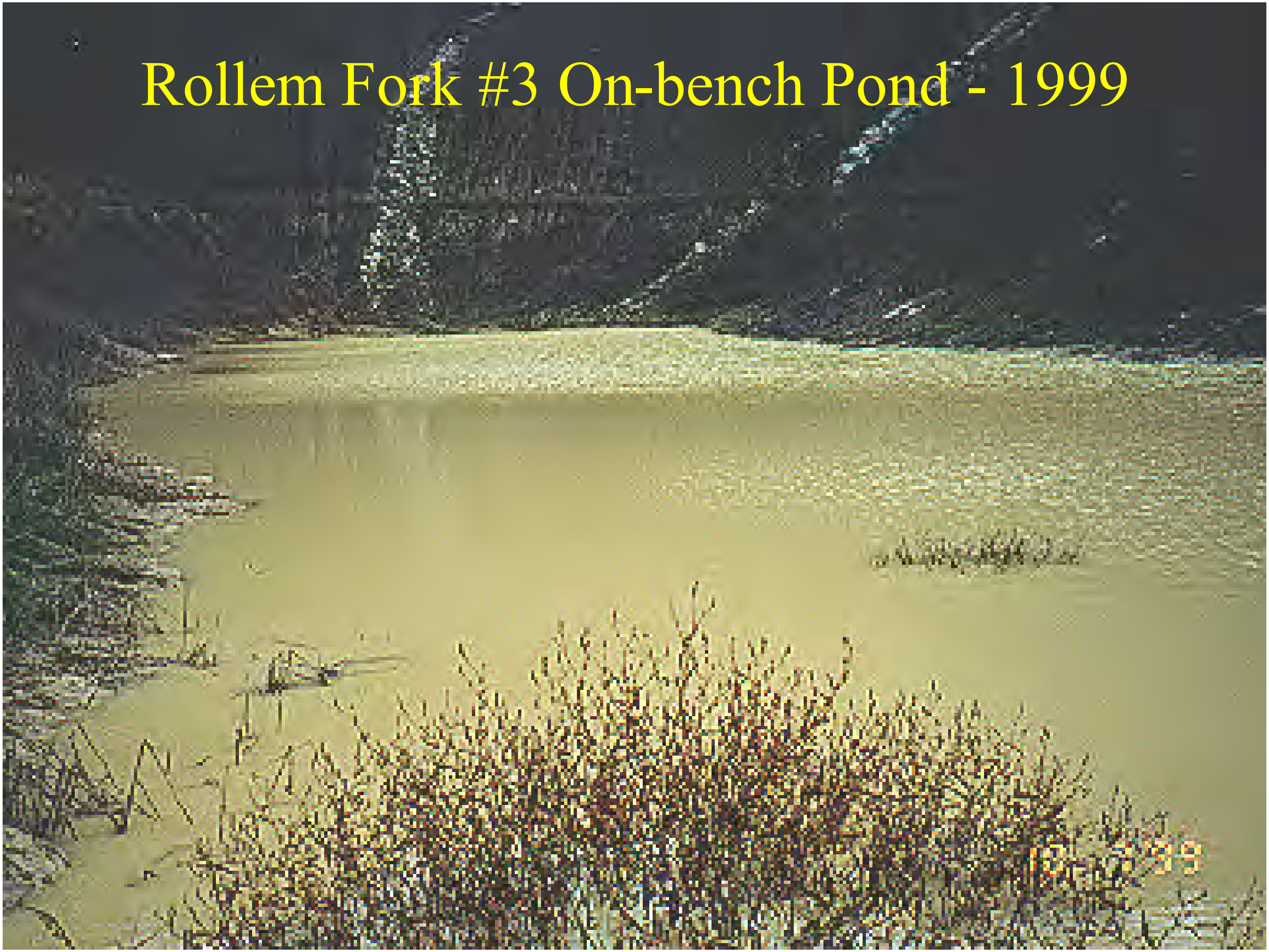

COAL
CATENARY

An Evaluation of Aquatic

Randy Maggard

Pen Coal Corporation

Rollem Fork #3 On-bench Pond - 1999



Rollem Fork On-Bench Pond #5 - 1997

Left Fork of Parker Branch #7 -1991

Macroinvertebrates

	Vance Branch -99	Rollem Fork -97	Left Fork -91
Taxa Richness	8	12	14

Rollem Fork Combination Ditch - 1999


Rollem Fork Sediment Ditch - 1997

Left Fork Sediment Ditch - 1994

Comparisons

- Headwater Streams vs. Wetlands and Ponds

Excess Spoil Disposal Configuration

Presented by:

John Morgan

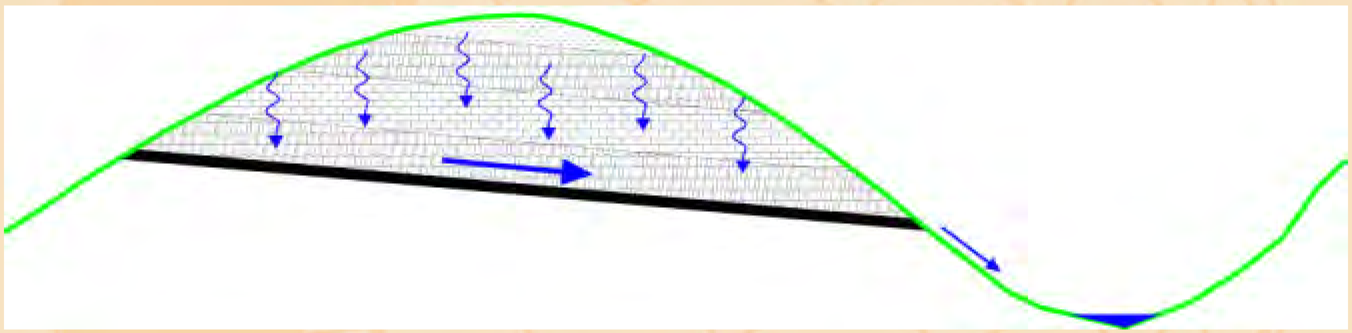
Why no water on backfill?

- High permeability of backfill
- Broken and mixed overburden from blasting and excavation
- Backfill has no defined horizons
- Change to pre-mining stratigraphy
- No aquicludes until pavement
- Infiltration from ditches

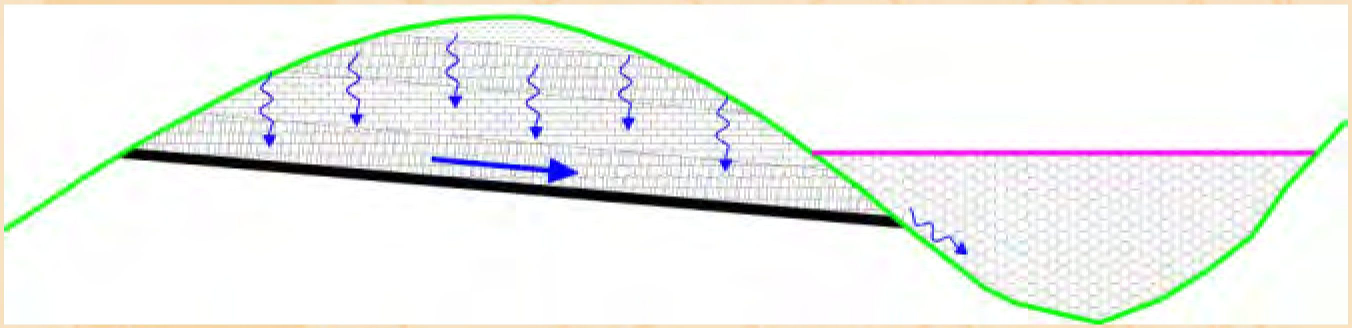
Where is water?

- Storm flow in ditches
- Subsurface flow on coal pavement
- Subsurface flow discharge at down dip outcrop
- Some outcrop discharges covered by valley fill
- Discharge at toe of valley fill
- Very few surface flows
- Some ponds on solid benches

Subsurface Flow



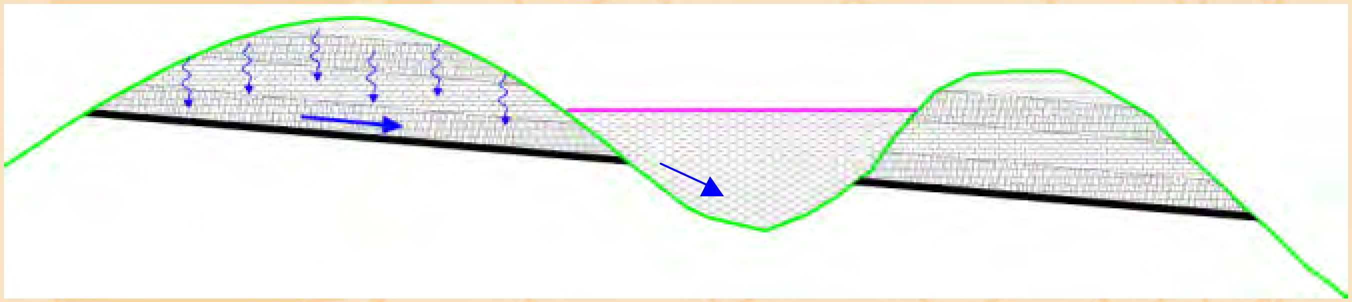
Subsurface Flow (with fill)



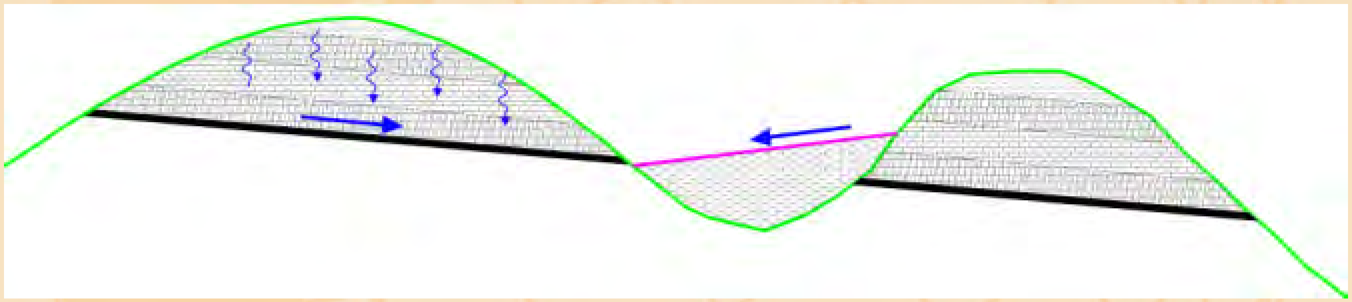
Alternative Backfill Configuration?

- Objectives
  - Intercept groundwater discharge
  - Decrease ditch gradients
- Alternative Configuration
  - Construct combination conventional / side-hill fill
  - Tilt top surface of valley fills to one side
  - Create incised groin ditch with flatter slope

Typical Valley Fill Regrade



Modified Valley Fill Regrade



Evaluation of skewed fill

- Advantages
  - Intercepts flow at outcrop
  - Collects some surface flow
  - Increases probability of perennial flow
- Disadvantages
  - Increased flow rate in single ditch
  - Concerns with regulatory stipulations for side hill fill
  - Some increase in fill haulage height

AOC Model

- Provides an objective and reproducible means to define AOC
- Allows a subjective approach to be replaced with a volumetric definition
- Optimizes the placement of spoil
- Volumetric approach gives operator flexibility over final design
- Allows landforming, stream restoration and aquatic habitat projects

Forest Restoration on a Closed Landfill: Rapid Addition of New Species by Bird Dispersal

GEORGE R. ROBINSON
STEVEN N. HANDEL

Department of Biological Sciences
Rutgers University
Piscataway, NJ 08855, U.S.A.

Abstract: *Urban areas often contain sizeable pockets of degraded land, such as inactive landfills, that could be reclaimed as wildlife habitat and as connecting links to enhance remnant natural areas. In the northeastern U.S., many such lands fail to undergo natural succession to woodland, instead retaining a weedy, herbaceous cover for many years. We hypothesize that seed dispersal is a limiting factor, and that a form of secondary succession could be stimulated by introducing clusters of trees and shrubs to attract avian seed dispersers. As a direct test, we censused a 1.5-ha experimental plantation on the Fresh Kills Landfill (Staten Island, New York) one year after installation, in search of evidence that the plantation was spreading or increasing in diversity. The 17 planted species, many from coastal scrub forests native to this region, were surviving well but contributed almost no seedlings to the area, in part because only 20% of the installed trees or shrubs were reproductive. Of the 1079 woody seedlings found, 95% came from sources outside the plantation; most (71%) were from fleshy-fruited, bird-dispersed plants from nearby woodland fringes. Although the restoration planting itself had not begun to produce seedlings, it did function as a site for attracting dispersers, who enriched the young community with 20 new species. One-fourth of all new recruits were from nine additional wind-dispersed species. Locations with a high ratio of trees to shrubs had proportionately more recruits, indicating that plant size contributed to disperser attraction. The density of new recruits of each species was dependent on distance from the nearest potential seed source. Introducing native species with the capacity to attract avian dispersers may be the key to success of many restoration programs.*

Paper submitted December 20, 1991; revised manuscript accepted September 21, 1992.

Restablecimiento del bosque en una clausura: Rápida adición de especies por aves dispersoras

Resumen: *Areas urbanas usualmente contienen nucleos aislados de tamaño considerable, de tierras degradadas, como vertederos públicos inactivos que pueden ser reclamados como hábitat para vida silvestre, y como vínculos de conección para ampliar áreas naturales remanentes. En el Noreste de Estados Unidos muchas de estas tierras fracasan en el proceso natural de sucesión hacia bosques, en vez retienen por muchos años una cubierta herbácea de malezas. Nuestra hipótesis es que la dispersión de las semillas es un factor limitante. Una forma de sucesión secundaria puede ser simulada introduciendo conglomerados de árboles y arbustos, para atraer aves dispersoras de semillas. Como test directo nosotros sensamos 1.5-ha de una plantación experimental en el vertedero público de "Fresh Kills" (Staten Island, New York) un año después de la instalación, en la búsqueda de evidencia que demuestre que la plantación fue dispersada o incrementó en diversidad. Las 17 especies plantadas, muchas de arbustos costeros nativos de la región, sobrevivieron bien, pero, prácticamente, no contribuyeron en semillas en el área, en parte porque sólamente el 20% de los árboles o arbustos instalados fueron reproductivos. EL 95% de las 1079 plántulas leñosas encontrados provienen de fuentes fuera de la plantación; la mayoría (71%) provinieron de frutos de plantas dispersadas por pájaros de tierras de bosques aledáneas. Si bien la restauración de la plantación en sí misma no ha comenzado a producir plántulas, ha funcionado como sitio para atraer dispersores, que han enriquecido las comunidades jóvenes con 20 nuevas especies. Un cuarto de todos los nuevos reclutas provinieron de nueve species dispersadas por el viento. Lugares con altas relaciones de árboles con respecto a arbustos tuvieron proporcionalmente más reclutas, indicando que el tamaño de la planta contribuyó a la atracción del dispersor. La densidad de los nuevos reclutas de cada especie fue dependiente de la distancia desde la fuente potencial de semillas más cercana. La introducción de especies nativas con la capacidad de atraer aves dispersoras puede ser la clave del suceso de muchos programas de restauración.*

Introduction

Restoration ecologists face many challenges as they attempt to coax or retain processes that regulate natural communities. Even when habitats are well prepared and species choices carefully made, successful restoration can be delayed or prevented by local environmental change, such as altered hydrologic patterns (Zedler 1988), competition from invading weeds (Bradshaw 1983), or herbivore damage (Archibold 1979; Anderson 1989). When change is anticipated as part of restoration planning, however, the outcome can be directed in favorable ways. For example, natural succession can be initiated and promoted during land reclamation and habitat restoration (Uhl 1988; Bradshaw 1989; Majer 1989; Luken 1990). Restoration planners can draw from a wealth of knowledge on the ecological processes that accompany successional change, in particular the role of plant reproduction and dispersal during secondary succession (Archibold 1979; Uhl et al. 1982; McClanahan 1986; Aber 1987; Janzen 1988*a*, 1988*b*; Nepstad et al. 1991.)

When degraded lands are abandoned, they rarely change but instead persist as scars on urban and rural landscapes. We have examined a number of abandoned landfills in the New York metropolitan area and have been impressed by the failure of vegetation to develop either diversity or complexity on these sites. What ecologists in the northeastern United States have come to regard as normal succession from open field to woodland (see Pickett 1982) does not occur, or else occurs at a snail's pace. One can find occasional large trees growing on even the poorest, most exposed sites, but these are largely the products of a few wind-dispersed species (Stalter 1984). A likely explanation for the absence of natural succession is that appropriate seeds never arrive. Microsite limitations impose many "filters" on a developing forest community, such as interspecific competition, seed predation, and seedling herbivory (Werner & Harbeck 1982; Myster & McCarthy 1989; De Steven 1991*a*, Gill & Marks 1991), but initial differences in seed dispersal may be overwhelming (De Steven 1991*b*). We focus on this earliest part of secondary succession, the dispersal stage, and its significance in the restoration process.

During secondary succession, animals continuously transport seeds of woody species into open areas (Johnston & Odum 1956; Smith 1975; Guevara et al. 1986; Hoppe 1988; Saulei & Swaine 1988). This is particularly true in the formation of temperate deciduous forests in North America, where most mid-successional species are bird-dispersed (Howe & Smallwood 1982; Stapanian 1986; Willson 1986; Stiles 1989). In open fields, bird dispersers are attracted to trees and shrubs, which at a minimum provide perching sites (Debussche et al. 1982; Uhl et al. 1982; McDonnell & Stiles 1983; McDonnell 1986; McClanahan & Wolfe 1987; Campbell et al. 1990). The process is exponential, with positive feedback between increasing woody plant densities and increasing disperser visits. The fact that highly disturbed lands fail to undergo natural succession may be tied to the lack of a first pulse of woody recruitment—an exponential invasion curve can't get started.

In an effort to rehabilitate portions of the Fresh Kills Landfill (an 800-ha complex), the City of New York Department of Sanitation has begun a series of experimental plantings, including attempts to regenerate native forest communities. We examined one of these reforestation experiments to determine whether it was functioning as a seed source and as an attractant for dispersers. Our hypotheses for this study were:

(1) Native woody species can survive and grow on restored landfills and similar recovering sites, and their absence reflects a lack of natural dispersal. Alternatively, the site is unfavorable for these plants, regardless of dispersal patterns.

(2) The introduction of woody species can stimulate natural succession to a diverse woodland, provided native seed sources are nearby. Alternatively, seed is introduced into the landscape, regardless of the background vegetation.

(3) This attractive function is proportional to average plant size. Alternative hypotheses are that recruitment is instead proportional to planting density, or that dispersal is diffuse and not correlated with plant size or planting density.

Methods

In Fall 1989 and Spring 1990, 1.5 ha of an approximately 4-ha site on the Fresh Kills Landfill (Staten Island, New York; Fig. 1) was designated for restoration and planted with 18 species of trees and shrubs. The species, all of which are native to northeastern North America, were chosen as representative of a coastal scrub forest once found on Staten Island and still occurring on Long Island, New York (Olsvig et al. 1979), and coastal New Jersey (Robichaud & Buell 1973). Prior to planting, the site was covered with a 40-cm cap of highly compacted clay-shale subsoil (to prevent gas and water exchange between the landfill contents and the atmosphere, in accordance with local regulations), and then covered with a planting substrate of 60 cm of sandy mineral soil, into which approximately 15 cm of composted leaf mulch (a commercial nursery product) was incorporated. All soils and amendments were transported to the site from stocks stored at other locations. The planting substrate was graded from 30 to 90 cm deep on the site to create an undulating topography, characteristic of natural coastal sites. Elevation of the site ranged from sea level to 17 m.

Figure 1. Maps of (a) Staten Island, New York, (b) the Fresh Kills Landfill complex, and (c) the coastal woodland restoration area examined in this study. The four numbered sections in (b) are the landfill mounds, parts of which have been capped with impermeable liners and revegetated. Shaded areas in (c) represent the approximate positions of nearby woodland remnants.

Three separate vegetation mixes were installed in three different portions of the site: (1) a predominantly oak-shrub mix of 14 species, planted on a south-facing slope approximately 25 m inland from Main Creek; (2) a predominantly pine-shrub mix of 14 species, planted on a shallow, north-facing upland swale 30 to 90 m inland from the oak-shrub group; (3) an ericaceous shrub mix of six species, planted upslope from the two other areas on a predominantly east-facing slope (Fig. 1). In the analyses that follow, these are referred to as the oak, pine, and ericaceous sites. Approximately 3000 shrubs were planted in small clusters (6–12 plants of one species per cluster) among the three sites, and 500 trees were distributed over the oak and pine sites. In addition to woody species, each site was planted with native perennial grasses and seeded with a native wildflower mixture.

We censused the plantation in June 1991, during the second growing season after installation. We divided the three sites into 50 contiguous plots, each approximately 10 × 30 m. To study survival and reproductive status of the planted stock, we censused all trees, shrubs, and woody vines within the three sites. To estimate recruitment, we censused all seedlings of woody plants, identified by species. Living individuals were counted, measured, and categorized according to one of four sources: (1) deliberately planted as part of the restoration; (2) a seedling derived from one of the restoration plants (as a conservative estimate, this category included any seedling that matched a planted species that had reproduced in a site); (3) a seedling derived from a nearby source outside the restoration site; (4) a seedling or sprout that arrived in a root ball of a planted individual (presumably from a population at the source nursery).

Following the census, we surveyed the surrounding area to identify potential natural seed sources. Distances from nearby woodland remnants were estimated for all 50 plots to determine approximate minimum travel distances for each new species in every plot. Formal control plots (devoid of trees and shrubs) could not be established because the area surrounding the restoration site was mowed. As a substitute, we compared results informally with censuses taken on another nearby landfill to infer differences between background levels of woody plant recruitment and the putative effect of adding trees and shrubs. The Brookfield Landfill, also located on Staten Island—within 4 km of the Fresh Kills Landfill, was closed in 1985. The 20-ha site, which borders a 105-ha forested reserve, was seeded with commercial grasses upon closure and has since received no maintenance. It is similar to the Fresh Kills Landfill in soil types and surrounding vegetation. We censused all woody plants in three 0.5-ha plots, corresponding to the total area of the Fresh Kills Landfill restoration.

Results

Summary of Natural Recruitment

The majority of individuals and 17 of the 18 species planted were surviving (Table 1). Growth estimates indicate that most trees had moderate increases in girth (0 to 50%) over the first season, whereas most shrubs grew substantially in height, about 60% on average. A low proportion (19%) of plants were reproductive; most were either too young or perhaps suffered transplant shock. This is reflected in the very slight recruitment directly attributable to the plantation (0.4%; Table 2).

After one year, natural recruitment had boosted the

Table 1. Census data for trees and shrubs planted on the Fresh Kills Landfill dune restoration sites.

Species	Total count	Mean height (m)	Number reproductive	New seedlings
Amelanchier stolonifera	178	1.33	145	1
Arctostaphylos uva-ursi	21	0.22	0	0
Leiophyllum buxifolium	4	1.12	0	0
Lyonia mariana	12	0.32	6	0
Myrica pensylvanica	781	0.74	86	0
Pinus rigida	87	1.48	0	0
Pinus virginiana	78	1.67	1	0
Prunus maritima	523	0.66	43	1
Aronia arbutifolia	219	1.20	160	0
Quercus ilicifolia	65	1.13	33	2
Quercus marilandica	47	1.52	9	0
Quercus palustris	4	2.75	0	0
Quercus phellos	59	4.16	0	0
Quercus stellata	28	2.20	8	1
Rhus glabra	14	1.05	13	0
Vaccinium angustifolium	564	0.12	12	0
Vaccinium corymbosum	240	0.42	43	0
Totals	2924	0.80	559	5

All species are native to the region and dispersed by animals. Total count is the number of planted individuals censused throughout the three planted sites. New seedlings were recruits generated by the planted stock.

woody species count from 18 to 50, with the addition of 14 tree, 10 shrub, and 8 vine species (Table 2). Nine of the 32 recruiting species were probably carried in by wind, 20 by birds or mammals. Three additional species and a total of 46 recruits probably arrived via soils in the nursery root balls. In general, for every three installed plants, natural dispersal added a new individual to the community during the first year, for a total of over 1000 woody volunteers.

Recruitment, Plant Density, and Plant Size

Naturally recruiting species totalled 24 in the oak mix, 22 in the pine mix, and 17 in the ericaceous mix. Planting densities varied among the three groups, but recruitment rates (ratios of recruits to installed plants) when adjusted for these differences were similar (oak mix, 0.34; pine mix, 0.34; ericaceous mix, 0.32). The number of new recruits per plot was positively correlated with the number of transplants per plot ($R^2 = 0.11$, $p = 0.02$). The spread of seedlings was diffuse, however, and we could detect no clear correspondence between the number of recruiting seedlings and distance to a planted tree or shrub. An exception was black cherry (*Prunus serotina*), which tended to occur in small clusters in the vicinity of trees.

Results of other research (McDonnell 1986) indicate that most local fruit-eating birds will not perch on plants below a minimum height (1.5 to 2 m). All the planted trees we examined were taller than 1.5 m, and most shrubs were shorter. Since numbers of trees and shrubs varied independently among plots, we compared the ratio of planted trees to shrubs with the number of new recruits in each plot (for those plots with trees). Rank correlations indicate higher recruitment in plots with proportionately more tall plants (Kendall Tau = 0.24, $z = 2.10$, one-tailed $p = 0.01$).

Recruitment and Distance from Seed Source

We located potential nearby natural sources, in the form of fruiting adults in fringing woodlands, for most of the newly recruiting species (Table 2). The principal exceptions were those that recruited from root ball soils, and a commonly-planted shade tree, *Albizia julibrissin*. This species, which was found in several plots, may have been transported as a contaminant in soils or mulch. Three-fourths of naturally recruiting plants (745 of 1028) were bird-dispersed species. Mean minimum distances traveled (to a plot from the nearest potential natural seed source) were nearly twice as long for wind-dispersed species (210 ± 92 m) as for those dispersed by animals (129 ± 55 m). For bird-dispersed plants, seedling densities per plot were significantly dependent on distance from the nearest putative seed source for each species, although with considerable variation (regression statistics with 95% c.i.: seedling number = 12.98 − 1.94 ± 1.13 (log distance); $R^2 = 0.05$). No significant relationship was evident for wind-dispersed plants (seedling number = −0.44 + 0.53 ± 0.81 (log distance); $R^2 = 0.01$).

Comparisons with Other Landfill Sites

Without knowledge of a background invasion rate, it is problematic to attribute recruitment of bird-dispersed

Table 2. Census data for woody species naturally recruiting during the first season following installation of the Fresh Kills restoration.

Species	*Origin*	*Total count*	*Distance (m)*	*Principal vector*
Acer rubrum	native	14	228 (50)	wind
Ailanthus altissima	alien	65	299 (70)	wind
Albizia julibrissin	alien	47		wind
Baccharis halimifolia	native	64	162 (21)	wind
Campsis radicans	native*	19	124 (51)	animal
Celastrus orbiculatus	alien	77	131 (50)	animal
Comptonia peregrina	native	22	142 (21)	animal
Cornus stolonifera	native	2	215	animal
Crataegus sp.	native	1		nursery soil
Eleagnus commutata	native*	6		nursery soil
Juglans nigra	native	1		animal
Juniperus virginiana	native	1	397	animal
Liquidambar styraciflua	native	37	299 (55)	wind
Lonicera japonica	alien	2	124 (103)	animal
Parthenocissus quinquefolia	native	40	139 (51)	animal
Paulownia tomentosa	alien	1	179	wind
Populus tremuloides	native	29	143 (60)	wind
Prunus serotina	native	108	120 (47)	animal
Quercus prinus	native	1		animal
Quercus velutina	native	1		nursery soil
Rhus aromatica	native	1		animal
Rhus copallina	native	276	125 (52)	animal
Rhus glabra	native	86	133 (26)	animal
Robinia pseudoacacia	native*	34	121 (46)	wind
Rosa multiflora	alien	5	81 (45)	animal
Rosa sp.	native	2	115 (91)	animal
Rubus sp.	native	87	128 (53)	animal
Salix discolor	native	1	287	wind
Sassafras albidum	native	8		animal
Smilax sp.	native	6	141 (61)	animal
Toxicodendron radicans	native	26	121 (55)	animal
Vitis sp.	native	4	106 (41)	animal
	Total count	1074		

** Native to the U.S. but not to Staten Island (Buegler & Parisio 1982).*
Total count is the number of individuals censused throughout the plantation. Distance is the minimum mean travel distance (± 1 SD) from the nearest identified seed source to each plot where a recruit was found. Species without a distance value arrived in nursery soils or from unknown sources.

plants to some attractive feature of the plantation. Censuses of the Brookfield Landfill, where trees and shrubs were never planted, indicate that some woody plants were recruiting. Nineteen species were found, only six of which were wind-dispersed (therefore, animal dispersal was occurring). Stem densities were relatively low however, 145/ha, compared with 640/ha at the Fresh Kills site. Judging by their sizes, approximately half of the recruiting plants were recent seedlings, and this roughly translates to an eight-fold lower rate of annual recruitment on the unplanted site.

Another comparison was afforded by an experimental woodland planted in 1976 on part of the Edgeboro Landfill, East Brunswick, New Jersey (Gilman et al. 1985). By 1990, this plantation had been invaded by a great many new trees, shrubs, and vines—mostly native, berry-bearing species, from nearby riparian forest remnants (Robinson et al. 1992). Stem density of recruits was about 3100/ha, or nearly three times that of the original planted trees and shrubs.

Discussion

Restoration programs are often trial-and-error endeavors, but firmer ecological bases are being developed. For example, recent studies indicate that the pace of restoration and the development of wildlife habitat increase with greater vegetation complexity (Gibson et al. 1985; Parmenter et al. 1985; Schuster & Hutnick 1987; McKell 1989). The natural value of revegetated landfills and similar highly disturbed sites could be greatly improved by landscaping with attention to this need for vegetative complexity. The prospects for using restored lands to enhance biodiversity are sufficiently strong to deserve attention (Bradshaw & Chadwick 1980; Cairns 1988;

Office of Technology Assessment Task Force 1988). If the vegetation were improved, these areas (which represent thousands of hectares of unused land) could contribute significantly to local biodiversity by adding wildlife habitat that would help link remnants of natural forests and wetlands. Urban greenbelts could be enhanced or buffered, and habitat of at least marginal quality could be added to important bird migration corridors (Kane 1991). On the other hand, full-scale landscaping to restore such large areas can be prohibitively expensive. A hopeful alternative is that a modest planting of an appropriate mix of native species can promote the development of diverse natural communities in places that would otherwise remain wastelands.

We are particularly interested in the role of nearby remnant vegetation in promoting the rehabilitation of disturbed sites via secondary succession. By providing inocula of appropriate plants and by paying attention to reproductive ecology, many new individuals and species might be added to degraded lands without increasing the planting effort. In this light, static landscape designs should be replaced with dynamic successional processes that introduce a continuous stream of new elements. This approach has origins in theories of "nucleation" (Yarranton & Morrison 1974; Austin & Belbin 1981), in which patches of vegetation are seen as foci for the rapid spread of invading species (see McClanahan 1986; Moody & Mack 1988). The potential of nucleation is being explored in restoration studies throughout the world. Our results indicate that (1) a variety of woody species can grow in the highly modified soils and open slopes of old landfills, (2) the recruitment phases of succession can be stimulated by planting woody species to promote the invasion of others, and (3) plant size may play a role in determining the strength of that stimulation.

Although survival was high, the restoration plants in this study (chosen on the basis of availability, aesthetic appeal, and site compatibility) contributed very few seedlings. Soils in the immediate vicinity of planted trees and shrubs were covered with a mulching layer of bark chips (from shredded conifers), and this may have been a poor medium for germination. Alternatively, recruits under fruiting plants may have been preferentially removed by herbivores, which could have been attracted to clumped seedlings. In any case, this general result points out the need to monitor restoration sites in order to determine the amount of internal recruitment taking place. It also highlights the importance of reproductive ecology in restoration planning (Bradshaw 1983; Aber 1987; Ashby 1987). A different choice of species might have yielded more seed production and spread, and attention to early reproductive capacity ought to be included in restoration planning (Robinson et al. 1992).

Without true controls, we can only infer that planting trees and shrubs made a substantial difference in recruitment rates. The positive relationship between planting densities and numbers of recruits lends strength to this interpretation, particularly in light of our census results from the two other landfill sites. Compared to commonly reported seed shadow distances for bird-dispersed species (see Howe & Smallwood 1982; Hoppe 1988; Stiles 1989; Izhaki et al. 1991), our estimates of recruitment distances are quite high, and it is likely that many recruits we observed were outliers along distribution paths. Failure to pick up such outliers may be a major limitation to succession on open, highly-disturbed areas. Wind-dispersed recruits apparently travelled further, and their densities were independent of distance from nearest parent plants. Such differences in recruitment rates and distance effects underscore the need to consider the role of dispersal vectors in succession-based restoration programs (Janzen 1988*a*).

Since plots with proportionately more trees had higher recruitment, the simple conclusion is that some tall species ought to be included in restoration plantings of this type (although "tall" in this case might mean a height of 2 m). This issue is an important one in forest restoration programs, since larger trees and shrubs are less likely to survive transplanting, are more susceptible to the stressful environment of open, exposed sites, and carry much higher purchase and installation costs.

Several of the newly arrived species (*Ailanthus altissima, Celastrus orbiculata, Rosa multiflora,* and *Lonicera japonica*) are highly invasive weeds, with the capacity to dominate a site and exclude native species (Hu 1979; Decker & Enck 1987; Harrington & Howell 1990). A management scheme for their control should be part of any restoration protocol, and, since they appeared within the first year, control measures should be swift. Stimulating natural succession by attracting dispersers might be a poor technique when it leads to the unmanaged spread of weedy aliens.

More-detailed, experimental study will be required if specific restoration protocols are to be derived. For example, what kinds of species can be counted on for natural recruitment, and which species will need to be artificially introduced? Are larger plants, beyond some threshold size, more effective than smaller ones? How close should natural seed sources be to ensure optimal dispersal? How should plants be distributed to maximize pollination, disperser attraction, seedling recruitment, and subsequent woodland succession? Together, these issues represent the need to include plant reproductive ecology in the conceptual background of restoration planning. Answers to these and similar questions will provide firmer ecological bases on which to build sound ecological restoration programs.

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Downstream Impacts of Surface Mining
And Valley Fill Construction

by

Randall Maggard, Ed Kirk

Abstract Pen Coal Corporation has been conducting a detailed monitoring program on Trough Fork watershed to determine the downstream impact of mining operations. This program involves the monitoring of both water chemistry and benthic macroinvertebrates at upstream and downstream locations during the spring and fall since 1995. The study was initiated prior to any mining activity, and will continue through the completion of mining and reclamation activities. This report is a summary of the data gathered as of the fall of 1998.

Key Words: Watershed, Perennial Stream, Intermittent Stream, Water Chemistry, Benthic Macroinvertebrates, Valley Fill, Wildlife Habitat.

Introduction

Pen Coal Corporation has extensive mining operations located near Dunlow, in southern Wayne County, West Virginia. The operations consist of an active underground mine in the Coalburg Seam, two active underground mines and two active surface mines in the 5-Block seam, a preparation plant, a refuse fill, and an impoundment. Each of these operations are located in the watershed of the East Fork of Twelvepole Creek.

Mining operations began at the Honey Branch Surface Mine in September 1987. This operation consisted of contour mining and valley fill construction associated with the Coalburg seam. During the summer of 1988 Pen Coal began mining operations at the Frank Branch Surface Mine that involved contour mining and point removal with valley fill construction associated with the 5-Block seam.

Note:
1) Paper presented at the 1999 Annual Meeting of the West Virginia Acid Mine Drainage Task Force, Morgantown, WV, April 13 & 14, 1999.
2) Randall Maggard, Environmental Specialist, Pen Coal Corporation, Dunlow, WV. R.E.I. Consultants, Inc., Beaver, WV, Ed Kirk, Aquatic Biologist.
3) Publication in this proceedings does not prevent authors from publishing their manuscripts, whole or in part, in other publication outlets.

The mining operations involving the 5-Block seam have continued to expand to involve the drainage areas of Kiah Creek and Trough Fork, which are also tributaries of the East Fork of Twelvepole Creek.

Some minor water quality problems were detected during 1990, which were easily treated and corrected. As mining progressed northward, the elevation of the 5-Block seam has continued to drop closer to drainage. This created some operational problems due to the lack of available valley fill areas. This also caused an increase in the quantity of surface water which entered the mining area. During 1993, the water quality problem associated with the surface mining of the 5-Block seam became more pronounced, and required a more intensive effort to control and abate. Pen Coal began an extensive "Water Quality Improvement Plan" in February 1994 to determine the most cost effective method for treatment of the existing problems and methods to prevent or minimize future problems.

As part of the "Water Quality Improvement Plan", Pen Coal began an extensive benthic macroinvertebrate monitoring program in the affected watersheds during the fall of 1995. The Trough Fork watershed was undisturbed during the fall of 1995, but mining was projected for the area, therefore Trough Fork was included in the monitoring program. This monitoring has continued each spring and fall since that time.

Statement of Purpose

The purpose of this paper is to share the data that Pen Coal Corporation has gathered with the coal mining industry and other interested parties. The writers would like to specifically address the following points of significance:

?? The most dramatic change which occurs during surface mining with valley fill construction is the disturbance and associated change in land configuration and vegetation.

?? The chemical composition (quality) and volume of the water downstream from these operations do change. These changes will be discussed in more detail.

?? The benthic macroinvertebrate communities that exist downstream of these operations do change as a result of the changes in the chemical and physical characteristics of the receiving streams.

Surface Impacts

Trough Fork is a first order stream which has a watershed of approximately 2,882 acres. Pen Coal's currently permitted mining activities will impact approximately 580 acres, or 20% of the Trough Fork watershed.

Trough Fork has approximately 16,200 linear feet of perennial stream with approximately 44,400 linear feet of intermittent tributaries (Based on USGS topographic mapping). The value of these intermittent tributaries is an item that is currently under hot debate. The mining activities by Pen Coal will directly impact approximately 19,800 linear feet of these tributaries either by direct mineral removal, or by valley fill construction. This amounts to about 44% of the intermittent tributaries of Trough Fork. Only one of these individual tributaries, Vance Branch, exceeded 250 acres.

The post-mining configuration of the reclaimed mine sites will consist of six valley fills of various sizes, eighteen ponds, approximately 40,000 linear feet of sediment or diversion channels, and approximately 575 acres of regraded land. This land will then be revegetated with various grasses, legumes, shrubs and trees to enhance wildlife habitat. This is what will replace the pre-mining site that originally consisted of 580 acres of unmanaged forestland and 19,800 linear feet of intermittent streams.

Methods

Benthic Macroinvertebrates

Benthic macroinvertebrates were collected following a modified Rapid Bioassessment Protocol III (EPA/440/4-89/001) at both an upstream (BM-005) station and a downstream (BM-006) station on Trough Fork in October and April since 1995 (Figure 1). An Ellis-Rutter™ Portable Invertebrate Box Sampler (PIBS) with a sample area of $0.1 m^2$ was utilized in the both the riffle habitats and in a slower run/pool habitat for a total of three replicates per station. A standard kick-net seine (sample area = $1.0 m^2$) was also utilized at each station, but in a run/pool habitat. Invertebrate samples were preserved in 10% formalin, picked under microscopes, and detrital material was checked a second time to insure that no individuals were missed. All macroinvertebrates were indentified to lowest practical taxonomic level, enumerated, and several metrics were calculated using the data.

Water Chemistry

Water samples were collected in October and April since 1995 at both the upstream (BM-005) site and the downstream (BM-006) site (Figure 1), appropriately preserved, and transported to R.E.I. Consultant's laboratory for analysis. The Water Quality Parameters measured for each sampling site are listed below:

Flow	Sulfates
pH	Sodium
Conductivity	Aluminum
TDS	Calcium
TSS	Iron
Hardness	Magnesium
Alkalinity	Manganese
Acidity	Chlorides

Parameters analyzed in-the-field were pH, conductivity, dissolved oxygen, water temperature, and stream flows. These parameters are good indicators of the water quality of a particular station, and when used in conjunction with the macroinvertebrate data, can indicate any changes which occur as one progresses downstream.

Some of the individual parameters are described in more detail as to their role in evaluating water quality below:

Flow:
The flow is an indicator of the surface and groundwater discharges in the watershed.

pH:
The pH is a measure of the hydrogen ion concentration and is preferred to be in the 6.5 to 8.5 range in natural waters.

Conductivity:
The conductivity is the ability of a solution to conduct electrical current. The conductivity is directly related to the amount of materials dissolved in the water.

TDS:
The TDS (Total Dissolved Solids) is a measure of the amount of dissolved materials in the water is directly related to the conductivity, and generally preferred to be less than 1000 mg/l.

TSS:
The TSS (Total Suspended Solids) is a measure of the undissolved solids which are suspended in the water. Any land disturbance can lead to increases in TSS.

Hardness:
The hardness is typically a measure of the amount of calcium, magnesium and iron in the water. The hardness typically increases as the concentration of these elements increase.

Alkalinity:
The capacity of water to accept hydrogen ions is called alkalinity. This is important in the chemistry and biology of natural waters. Alkalinity serves as a pH buffer and reservoir for inorganic carbon, thus helping to determine the ability of water to support algal growth and other aquatic life. Alkalinity can be used as a measure of water fertility. It is important to distinguish between an elevated pH and high alkalinity, the difference is pH is an intensity factor while alkalinity is a capacity factor.

Acidity:
The capacity of water to neutralize OH^- is referred to as acidity. The acidity in natural waters generally results from the presence of weak acids such as CO_2 and acidic metal ions, particularly Fe^{3+}.

Sulfate:
The sulfate content of natural waters in the Appalachian region is typically low in undisturbed watersheds (10 to 50 mg/1). When surface disturbance occurs, such as mining or highway construction, and sulfide bearing rock is exposed to weathering, sulfate concentrations typically increase in the watersheds. Sulfate concentrations in the 300 to 400 mg/l range can give water a bitter taste an concentrations of 600 to 1000 mg/l has laxative effect.

Sodium:
The sodium concentration of natural waters in the Appalachian region is typically very low and increases area usually attributed to human activities such as highway salting, water treatment or oil and gas production.

Aluminum:
The aluminum concentrations in natural waters is typically attributed to suspended clay particles or to dissolved aluminum if severe acid mine drainage is encountered.

Calcium:
The most common cation in most freshwater systems is calcium and often has the most influence on aquatic chemistry. Calcium is a key element in many geochemical processes and minerals constitute the primary sources of the calcium ion in water.

Iron:
The iron concentrations in natural waters in the Appalachian region vary greatly. The sources of iron can range from suspended iron clay minerals to dissolved iron from natural seeps or discharges from manmade disturbances such as mining or construction activities.

Magnesium:
Probably the second most common cation in most freshwater, magnesium behaves similar to calcium and is usually associated

with calcium concentrations and contributes to hardness.

Manganese:

The manganese concentrations in natural waters in the Appalachian region vary. The sources are typically the result of weathering of sedimentary rocks. The concentrations can increase dramatically when large quantities of rock are exposed to weathering such as surface mining or highway construction.

Chlorides:

The chloride concentrations are typically low in natural waters in the Appalachian region but may increase as a result of highway de-icing or oil and gas production.

Results

Benthic Macroinvertebrates

In general, the total number of benthic macroinvertebrate individuals has increased dramatically at the upstream (BM-005) site since pre-mining conditions in October 1995 from 193 individuals in April 1996 to 1,009 individuals in October 1998 (Tables 3 and 4). In addition, taxa richness has increased slightly at the upstream stations since October 1995. The number of Ephemeroptera, Plecopetera, and Trichoptera (EPT) groups has also slightly increased since pre-mining conditions in October 1995. A trend in the benthic community’s tolerance is hard to distinguish at the upstream site, but a slight negative trend towards a more tolerant community is somewhat evident from the increasing Hilsenhoff Biotic Index (HBI) as well as the relative percentages within the three tolerance groups. The decreasing Diversity and Evenness measures also indicate a slightly less diverse and less equitable community at the upstream site since October 1995 (Tables 3 and 4).

In general, the total number of benthic macroinvertebrate individuals has most likely increased at the downstream station (BM-006) since pre-mining conditions in October 1995 from 496 individuals in October 1995 to 2,777 individuals in October 1998. Taxa richness may have increased slightly at the downstream station. Number of EPT taxa has probably remained unchanged at the downstream station (Tables 3 and 4). The macroinvertebrate community, however, has depicted a negative trend in the tolerance as indicated by the increasing HBI, and by the changes of percentages within the three tolerance groups. The decreasing Diversity and Evenness measures also indicate a somewhat less diverse and less equitable population of aquatic macroinvertebrates at the downstream station since October 1995.

Water Chemistry

In general, all parameters analyzed have remained relatively unchanged at the upstream (BM-005) site since pre-mining samples were collected in October 1995 (Tables 1 and 2). However, at the downstream site (BM-006), several parameters have increased since pre-mining conditions in October 1995. These include conductivity, TDS, TSS, hardness, alkalinity, sulfates, sodium, calcium, and magnesium. Those parameters which have exhibited dramatic increases at the downstream site are conductivity (64 ?mhos in April 1996 to 1061 ?mhos in October 1998), TDS 64 mg/1 in April 1996 to 727 mg/1 in October 1998), hardness (22.4 mg/1 in April 1996 to 303 mg/1 in April 1998), alkalinity (20.9 mg/1 in April 1996 to 137 mg/1 in October 1998), sulfates (15.3 mg/1 in April 1996 to 354 mg/1 in October 1998), sodium (1.05 mg/1 in April 1996 to 141 mg/1 in October 1998), calcium (4.44 mg/1 in April 1996 to 80.2 mg/1 in April 1998), and magnesium (2.74 mg/1 in April 1996 to 30.3 mg/1 in October 1998).

Discussion

The most significant change in water quality was the sulfate concentrations which were most likely attributed to the oxidation of sulfide bearing overburden exposed during the mining operations. Some water treatment have occurred during these operations to neutralize the acidity produced by the oxidation of pyritic overburden. The treatment chemicals utilized were calcium oxide and sodium hydroxide which most likely contributed to the dramatic increases which also were observed in the calcium and sodium concentrations at the downstream sampling site. There was also an increase in magnesium which was probably also attributed to the weathering of magnesium bearing clays. The other increases such as conductivity, TDS, hardness, and alkalinity are directly related to the previously discussed increases in sulfate, calcium, sodium, and magnesium.

A desirable increase that occurred, however, was the increase in alkalinity which was originally in the 20 mg/l range. This increase in alkalinity to the 60 to 100 mg/l range should provide a much more fertile aquatic habitat.

Another change which was observed has been the increase in base flow at the downstream sampling point when compared with the upstream sampling point during low flow conditions which are typical during the October sampling. These have been confirmed on numerous occasions by visual observations. Even though these flows are small, they are very critical to aquatic life. These increases in flows can more easily guarantee year round flows which then make a difference between a stream containing rich populations of benthic macroinvertebrates and fish, to streams completely drying up in the dryer seasons, which is obviously devastating to aquatic life.

As stated previously, many of the water chemistry parameters have increased several fold at the downstream site since pre-mining conditions existed in October 1995. It is interesting to note that although mining activities commenced in February 1996, changes in water chemistry were not observed until the October 1996 sampling event.

These increases in water chemistry constituents, however, were not observable in the aquatic macroinvertebrate data until possibly the April 1997 sampling event, but definitely by the October 1997 sampling event. The only observable negative trend at the downstream station has been the shift in community structure from a more pollution sensitive, more diverse, and more evenly distributed community to one which is more pollution tolerant, less diverse, and less evenly distributed. Nevertheless, total abundances of benthic macroinvertebrates has continued to increase, and taxa richness has probably increased slightly at the downstream station since mining activities commenced in February 1996.

Conclusions

Even though many individual water chemistry constituents of the water quality at Trough Fork's downstream site have continued to escalate, the catastrophic results once predicted within the benthic macroinvertebrate communities have not been observed. The changes in water chemistry would probably have occurred even if valley fills had not been constructed due to hydrologic interactions with the backfilled and regraded areas at the coal seam elevation and higher. The increases in dissolved solids occurred as a result of the unavoidable increased weathering of exposed rock during mining. Pen Coal will continue to study the Trough Fork watershed through the completion of mining and reclamation activities to determine the long-term impacts that the mining operation has on the watershed. Since Pen Coal began mining in the East Fork of Twelvepole Creek watershed in 1987, 70% of its thirteen surface mine permits involved mining and valley fill construction in watershed greater than 250 acres. The changes proposed by the various Regulatory Agencies regarding mining and valley fills in watersheds greater than 250 acres could significantly impact future mining operations for the entire coal industry. A careful review of existing data should be undertaken and thoroughly evaluated by proven scientific methods.

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BENTHIC MACROINVERTEBRATE STUDY OF HONEY BRANCH, ITS SEDIMENT CONTROL PONDS, AND ITS INFLUENCE ON THE EAST FORK OF TWELVEPOLE CREEK CONDUCTED 10/08/99

Conducted For:

PEN COAL CORPORATION
KIAH CREEK MINE OFFICE
P.O. BOX 191
DUNLOW, WEST VIRGINIA 25511

By:

ED J. KIRK, AQUATIC BIOLOGIST
R.E.I. CONSULTANTS, INCORPORATED
225 INDUSTRIAL PARK ROAD
BEAVER, WEST VIRGINIA 25813

11/24/99

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BENTHIC MACROINVERTEBRATE STUDY OF HONEY BRANCH, ITS SEDIMENT CONTROL PONDS, AND ITS INFLUENCE ON THE EAST FORK OF TWELVEPOLE CREEK CONDUCTED 10/08/99

INTRODUCTION

One of the first permitted valley fills in West Virginia was located on Honey Branch. Honey Branch is a first-order tributary of the East Fork of Twelvepole Creek in Lincoln County, in southwestern West Virginia. Contour surface mining activities began in 1987, and were completed in 1991. On going reclamation activities were performed during mining operations. The Honey Branch mining site received its Phase II bond reclamation last year.

In June 1987 Heer, Inc. performed a benthic macroinvertebrate survey to provide a biological assessment of Honey Branch prior to mining activities to satisfy requirements for permit application. In July 1987 the West Virginia Department of Environmental Protection (WV-DEP) performed an informal, qualitative biological survey to confirm the assessments of the stream prior to mining operations. Science Applications International Corporation (SAIC) conducted another survey of Honey Branch in June 1998 to assess the impacts of mining activities and valley fills on the Honey Branch waterway. Several sites sampled during the Heer, Inc. survey were able to be utilized during the SAIC study for direct comparisons to be accurately made. Other sites were not possible to be sampled because they had been completely covered by the construction of valley fills. This study, performed in October 1999 was conducted to verify the present conditions of Honey Branch since mining activities has long since ceased in the area, and to determine if Honey Branch has had any effect on its receiving stream, the East Fork of Twelvepole Creek. Another purpose for the current study came about as a response to the environmental protests on the initial permit submittion. Many of the identical stations which were sampled during previous studies were sampled for this study so that comparisons could be made between the studies, and so that inferences as to macroinvertebrate community trends could be evaluated.

Another purpose of this study was to provide an unbiased, professional examination of the sediment control ponds and sediment ditches which currently exist on Honey Branch. These would be studied as to their aquatic and wetland status, as well as their usefulness as quality habitats for fauna inhabiting the area. Because Pen Coal has acquired the property, the ponds and sediment ditches on Honey Branch are now considered to be permanent structures. Normally, according to the West Virginia Department of Environmental Protection-Office of Mining and Reclamation, upon completion of mining activities, constructed sediment control ponds and/or drainage ditches must be removed prior to being released from permitting regulations if they are considered as temporary structures. Breaching of the dam is therefore required from the point of view that in order to return the stream back to its original state, the stream channel must be change back to its original shape.

Policies within the West Virginia Department of Environmental Protection (WV-DEP) require biological surveys of streams prior to, and after issuance of National Pollutant Discharge Elimination System (NPDES) permits to adequately determine stream biota and potential biological development. Biological data, such as aquatic macroinvertebrate populations, in conjunction with physical and chemical water quality, and habitat data, provide valuable information that are used in the permit review process and are ultimately used to assist in establishing NPDES discharge limitations. These data also act as a powerful monitoring tool in identifying possible pollutant sources and/or habitat alterations and subsequent effects.

LOCATION OF STUDY SITES

The study area is located in Lincoln County approximately 3/4 mile north of the Mingo/Lincoln County line in southwest West Virginia. Honey Branch is a first-order tributary of the East Fork of Twelvepole Creek. The Honey Branch waterway extends approximately 1,500 feet and has a watershed area of approximately 609 acres. The forks of Honey Branch begin at an elevation of approximately 1,100 feet above sea level the stream travels northward to enter the East Fork of Twelvepole Creek at an elevation of approximately 750 feet above sea level.

Three stations were sampled on Honey Branch, at the toe of the primary valley fill, mid-way between the toe and the mouth of Honey Branch, and at the mouth of Honey Branch. Two stations were sampled on the East Fork of Twelvepole Creek, upstream from the confluence with Honey Branch, and downstream from the confluence with Honey Branch. The middle Honey Branch sediment control pond (Pond Number 2), the lower Honey Branch sediment control pond (Pond Number 1), and the sediment ditch on Honey Branch were also sampled.

METHODS OF INVESTIGATION

On October 08, 1999 measurements for flow, physical water quality, and chemical water quality were taken at each of the stream, pond, and sediment ditch stations. Benthic macroinvertebrate samples were also collected, and the habitat of the stations was evaluated. The individual methodologies are described below.

Physical Water Quality

Physical water quality was analyzed on-site at each station. Water temperature, Dissolved Oxygen (DO), pH, and conductivity was measured with a Hydrolab™ Minisonde multi-parameter probe. Flow was measured in the streams with a Marsh-McBirney™ Model 2000 portable flow meter. Stream widths, depths, and velocities were measured, and the resulting average discharge was reported for each station.

Water Chemistry

Water chemistry samples were collected at each station and returned to R.E.I. Consultants, Inc. for processing. Parameters analyzed included acidity, alkalinity, chloride, hardness, sulfate, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), fecal coliform, aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium, silver, sodium, thallium, and zinc.

Habitat

For the stream stations, habitat was assessed and rated on nine parameters in three categories using EPA's Rapid Bioassessment Protocols for Use in Streams and Rivers (EPA 440/4-89/001). For the pond and sediment ditch sites, habitat was described as to its quality for fish, macroinvertebrates, and wildlife by assessing the size, shape, sediment storage potential, substrate type, bank stability, and vegetation types.

Benthic Macroinvertebrates

A modified EPA Rapid Bioassessment Protocol III (EPA 440/4-89/001) was utilized in the collection of the benthic macroinvertebrate specimens. At each stream station, collections were made via an Ellis-Rutter™ Portable Invertebrate Box Sampler (PIBS) sampler fitted with a 350-?m mesh size net. The PIBS sampler has several advantages over the standard Surber™ sampler which makes it a desirable choice for the collection of aquatic macroinvertebrates. Sampler area was 0.10 m^2 per replicate. Two samples were taken in a faster flowing riffle area and a third in a slower run area at each station. A kick-net seine was also utilized at each station, but in a slower run/pool area. The kick-net was fitted with a 500-?m mesh size net, and sampled approximately a 1-m^2 area per replicate. For the pond and sediment ditch sites, collections were made via a Ponar grab sampler. The Ponar grab sampler has several features which make it a desirable choice for the collection of aquatic macroinvertebrates in lentic habitats such as ponds, lakes, as well as lotic deepwater habitats such as rivers. Sampler area was 81 $inch^2$ per replicate. Three samples were taken near the shoreline, and in the best available spots (lowest siltation, highest percentage of gravel/pebble substrate, highest vegetation) at each station.

Samples were placed in 1-l plastic containers, preserved in 35% formalin, and returned to the laboratory for processing. Samples were then picked under Unitron™ microscopes and detrital material was discarded only after a second check to insure that no macroinvertebrates had been missed. All macroinvertebrates were identified to lowest practical taxonomic level and enumerated. Several benthic macroinvertebrate metrics were then calculated for each station.

SPECIFIC STATION LOCATIONS / PHYSICAL DESCRIPTIONS

Upstream Honey Branch Station (Toe of Valley Fill)

This station was located on Honey Branch approximately 70 feet downstream from the toe of the primary valley fill (Photographs 1 - 2). This station corresponded to the same location which was sampled during the SAIC 1998 study. Where the benthic samples were collected the substrate was comprised of approximately 50% bedrock, 25% cobble, 20% gravel, and 5% sand and silt. Average stream width was approximately 3 feet. Average depth was approximately 3 inches where the physical water quality was measured. Average flow was 0.15 cubic feet/second. In-the-field water quality measurements (Table 1A) were as follows: water temperature 13.36?C, Dissolved Oxygen (DO) 6.82 mg/l, pH 6.60, conductivity 400 ?mhos. A very desirable amount of Coarse Particulate Organic Matter (CPOM) was present in the form of shredded and whole leaves, sticks, and some large woody debris increasing both the available substrate and the foodbase. The stream contained a fairly desirable ratio of pools, runs, and riffles. The deciduous forest canopy was partly shaded due to the fairly dense forest surrounding the stream. Surrounding vegetation consisted mostly of the trees. Streambanks were very well vegetated, but were steep and appeared to be moderately unstable.

Middle Honey Branch Station

This station (Photographs 3 - 4) was located on Honey Branch below the middle Honey Branch pond (Pond Number 2). This station corresponded to the same location which was sampled during the SAIC 1998 study. Where the benthic samples were collected the substrate was comprised of approximately 25% cobble, 50% gravel, and 25% sand and silt. Average stream width was approximately 3 feet. Average depth was approximately 3 inches where the physical water quality was measured. Average flow was 0.08 cubic feet/second. In-the-field water quality measurements (Table 1A) were as follows: water temperature 14.41?C, Dissolved Oxygen (DO) 7.74 mg/l, pH 7.91, conductivity 367 ?mhos. There was a moderate amount of Coarse Particulate Organic Matter (CPOM) which was present in the form of shredded and whole leaves increasing both the available substrate and the foodbase. The stream contained a fairly desirable ratio of pools, runs, and riffles. The deciduous forest canopy was open because the surrounding forest was farther from the stream at this location. Surrounding vegetation consisted mostly of grasses and other herbaceous vegetation. Streambanks were very well vegetated, and were not steep and appeared to be very stable.

Mouth of Honey Branch

This station was located at the mouth of Honey Branch before it entered the East Fork of Twelvepole Creek. This station also corresponded to the same location which was sampled during the SAIC 1998 study. Where the benthic samples were collected the substrate was comprised of approximately 5% boulder, 55% cobble, 30% gravel, 5% sand, and 5% silt. Average stream width was approximately 2.5 feet. Average depth was approximately 2 inches where the physical water quality was measured. Average flow was 0.11 cubic feet/second.

In-the-field water quality measurements (Table 1A) were as follows: water temperature 16.29?C, Dissolved Oxygen (DO) 6.64 mg/l, pH 7.92, conductivity 348 ?mhos. There was a very desirable amount of Coarse Particulate Organic Matter (CPOM) which was present in the form of shredded and whole leaves, sticks, and larger woody debris increasing both the available substrate and the foodbase. The stream contained a fairly desirable ratio of pools, runs, and riffles. The deciduous forest canopy was shaded due to the dense surrounding forest at this location. Surrounding vegetation consisted mostly of trees, but shrubs, grasses and other herbaceous vegetation was also present. Streambanks were moderately well vegetated, were somewhat steep, and appeared to be moderately stable.

Upstream East Fork of Twelvepole Creek

This station was located on Twelvepole Creek approximately 100 feet upstream from the confluence with Honey Branch. This station corresponded to the same location which was sampled during the SAIC 1998 study. Where the benthic samples were collected the substrate was comprised of approximately 40% cobble, 50% gravel, 5% sand, and 5% silt. Average stream width was approximately 25 feet. Average depth was approximately 4 inches where the physical water quality was measured. Average flow was 0.11 cubic feet/second. In-the-field water quality measurements (Table 1A) were as follows: water temperature 13.88?C, Dissolved Oxygen (DO) 4.69 mg/l, pH 7.16, conductivity 159 ?mhos. There was a desirable amount of Coarse Particulate Organic Matter (CPOM) which was present mainly in the form of shredded and whole leaves increasing both the available substrate and the foodbase. The stream was comprised mostly of large pools and runs; riffle areas were scarce at this location. The deciduous forest canopy was partly shaded at this location. Surrounding vegetation consisted mostly of trees, but grasses and other herbaceous vegetation was also along the streambanks. Streambanks were moderately well vegetated, were undercut at places, but appeared to be moderately stable.

Downstream East Fork of Twelvepole Creek

This station was located on Twelvepole Creek approximately 100 feet downstream from the confluence with Honey Branch. Where the benthic samples were collected the substrate was comprised of approximately 5% boulder, 30% cobble, 50% gravel, 10% sand, and 5% silt. Average stream width was approximately 20 feet. Average depth was approximately 4 inches where the physical water quality was measured. Average flow was 0.21 cubic feet/second. In-the-field water quality measurements (Table 1A) were as follows: water temperature 14.77?C, Dissolved Oxygen (DO) 6.56 mg/l, pH 7.50, conductivity 212 ?mhos. There was a desirable amount of Coarse Particulate Organic Matter (CPOM) which was present mainly in the form of shredded and whole leaves increasing both the available substrate and the foodbase. The stream was comprised of a fairly good ratio of pools, runs, and riffle areas at this location. The deciduous forest canopy was partly shaded at this location. Surrounding vegetation consisted mostly of trees, but grasses and other herbaceous vegetation was also along the streambanks. Streambanks were moderately well vegetated, were undercut at places, but appeared to be moderately stable.

Honey Branch's Middle Pond (Pond Number 2)

This station was located on Honey Branch, and was constructed in 1988 (Photograph 5). The pond has an area of approximately 0.53 acres. The existing water depth was about 4 feet. Due to the pond being over 10 years old, the banks were 100% vegetated, and this was with various grasses, rushes, sweet flag, woolgrass, golden rod, greenbrier, and alders. Aquatic vegetation was comprised of milfoil (Myriofyllum sp.), pondweed (Potamogeton sp.), and cattails. Fish were present, but not positively identified to species. The banks were not steep along one side, but were stable due to their overall steepness, heavy vegetation, and established soil properties. No signs of erosion were present. There was some pond cover present due to the closer distance from the surrounding deciduous forest, and from the heavy vegetation surrounding the shoreline areas. The substrate was comprised mostly of silt with large abundances of detrital material (Table 4B).

Honey Branch's Lower Pond (Pond Number 1)

This station was located on Honey Branch, and was also constructed in 1988 (Photograph 6). This large pond is approximately 500 feet in length, and is approximately 300 feet wide, and has an area of approximately 1.01 acres. The elevation of the pond's bottom is approximately 780 feet above sea level. The existing water depth was about 6 feet. Due to the pond being over 10 years old, the banks were 100% vegetated, and this was with various grasses, rushes, sedges, sweet flag, woolgrass, golden rod, greenbrier, alders, and willows. Aquatic vegetation was comprised of cattails. Fish and bullfrogs were present, but were not positively identified to species. The banks were only steep along one side, but were stable due to their heavy vegetation, and well established soils. No signs of erosion were present. There was some pond cover present due to the close distance from the surrounding deciduous forest, and from the heavy vegetation surrounding the shoreline areas. The substrate was comprised mostly of silt with very large abundances of detrital material (Table 4B).

Honey Branch Sediment Ditch

This station was located on Honey Branch, and was constructed in 1988 (Photographs 7 - 8). The sediment ditch is approximately 100 feet in length, is approximately 20 feet wide, and has an area of approximately 0.05 acres. The existing water depth was only about a foot. Because the sediment ditch was constructed over ten years ago, the banks were very well vegetated with grasses, sedges, autumn olive, alder, scarlet maple, and box elder. Aquatic vegetation consisted primarily of cattails. The banks were not too steep along the hillsides, and were noticeably stable due to their low gradient and heavy vegetation. Soils were very well established due to the older age of this structure. This sediment ditch had noticeably lower dissolved oxygen levels (Table 1B) probably due to the heavy organic loading at this site. There was some canopy cover present due to the young trees growing and from the surrounding cattails. The substrate was comprised almost entirely of heavily organic and detrital materials (Table 4B).

PHYSICAL AND CHEMICAL WATER QUALITY ANALYSIS

Physical and chemical water quality was analyzed at each of the three stations sampled on Honey Branch, the two stations sampled on the East Fork of Twelvepole Creek, two of the sediment ponds on Honey Branch, and in Honey Branch's sediment ditch (Figure 1). The physical and chemical water quality results are presented in Tables 1A and 1B. Most values determined in Honey Branch were fairly similar with desirable DO levels, adequate pH levels, desirable alkalinity, low acidity, and low concentrations of metals. However, the dissolved solids, hardness, and sulfates were elevated, but were not considered limiting. Of the stations on the East Fork of Twelvepole Creek, most values were similar and desirable with near neutral pH levels, lower conductivity, lower hardness and alkalinity, and lower solids than for the stations on Honey Branch. The downstream East Fork station had higher levels of most parameters compared to the upstream East Fork station, but this was entirely due to the influence of Honey Branch. No values on the East Fork of Twelvepole Creek were considered limiting to the aquatic fauna as each station contained many individuals comprised of several taxa which are sensitive to pollutants.

For the Honey Branch sediment ponds and sediment ditch, most of the chemical values such as dissolved solids, hardness, sulfates, alkalinity, and most metals were very similar to those determined in the main channel of Honey Branch. Although several of these values were considered elevated, none were considered too limiting to the aquatic fauna, and it should be remembered that one of the primary purposes of the ponds and sediment ditches is for reducing the high levels of solids and metals by settling them out prior to reaching the downstream portions of the receiving streams.

Based on these data, Honey Branch can be classified as a moderate fertility, high buffering capacity, hard-water stream within the areas sampled; the East Fork of Twelvepole Creek can be classified as moderate fertility, moderate buffering capacity, hard-water stream within the areas sampled.

HABITAT ASSESSMENT

Stream Parameters

Several habitat measurements were calculated (Table 4A) for each of the stations sampled on Honey Branch and the East Fork of Twelvepole Creek. The individual parameters are described below.

Parameter 1. Bottom Substrate - The availability of habitat for support of aquatic organisms. A variety of substrate materials and habitat types is desirable. The bottom substrate is evaluated and rated by observation.

Parameter 2. Embeddedness - The degree to which boulders, rubble, or gravel are surrounded by fine sediment indicates suitability of the stream substrate as habitat for benthic macroinvertebrates as well as for fish spawning and egg incubation. Embeddedness is evaluated by visual observation of the degree to which larger particles are surrounded by sediment.

Parameter 3. Stream Flow - Stream flow relates to the ability of a stream to provide and maintain a stable aquatic environment.

Parameter 4. Channel Alteration - The character of sediment deposits from upstream is an indication of the severity of watershed and bank erosion and stability of the stream system. Channelization decreases stream sinuosity, thereby increasing stream velocity and the potential for scouring.

Parameter 5. Bottom Scouring and Deposition - These parameters relate to the destruction of instream habitat resulting from channel alterations. Deposition and scouring is rated by estimating the percentage of an evaluated reach that is scoured or silted.

Parameter 6. Pool/Riffle or Run/Bend Ratio - These parameters assume that a stream with riffles or bends provides more diverse habitat than a straight or uniform depth stream. The ratio is calculated by dividing the average distance between riffles or bends by the average stream width.

Parameter 7. Bank Stability - Bank stability is rated by observing existing or potential detachment of soil from the upper and lower stream bank and its potential movement into the stream. Streams with poor banks will often have poor instream habitat.

Parameter 8. Bank Vegetative Stability - Bank soil is generally held in place by plant root systems. An estimate of the density of bank vegetation covering the bank provides an indication of bank stability and potential instream sedimentation.

Parameter 9. Streamside Cover - Streamside cover vegetation is evaluated in terms of provision of stream-shading and escape cover for fish. A rating is obtained by visually determining the dominant vegetation type covering the exposed stream bottom, bank, and top of bank. Riparian vegetation dominated by shrubs and trees provides the CPOM source in allochthonous systems.

Sediment Pond and Sediment Ditch Measurements

Several habitat measurements were also determined (Table 4B) at each of the Honey Branch pond and sediment ditch sites sampled. The individual parameters are described below.

Pond/Ditch Surface Acreage - Actual size of the structure in acres. Smaller, shallower ponds and ditches, may not last as long or have as much sediment holding potential, but they will have a larger wetland value as there is less open water and more wetland vegetated area.

Length x Width - Longer, narrower ponds and sediment ditches will eventually have better wetland values for filtering incoming waters and provide more useable habitat for aquatic insects than wider, deeper ponds and sediment ditches.

Accumulative Sediment Storage Potential - Amount of sediment the structure can potentially hold. Larger, deeper ponds and sediment ditches can obviously hold more sediments, but may not have as desirable “wetland” potential.

Bottom Substrate Type - The availability of habitat for support of aquatic organisms. A variety of substrate materials and habitat types is desirable. Substrates comprised of more gravel, pebble, and/or organic materials are more desirable than those comprised mostly of silt and clay.

Bank Stability - Bank stability is rated by observing existing or potential detachment of soil from the upper and lower banks and its potential movement into the structure. Ponds and ditches with poor banks will often have poor instream habitat.

Bank Vegetative Stability - Bank soil is generally held in place by plant root systems. An estimate of the density of bank vegetation covering the bank provides an indication of bank stability and potential instream sedimentation.

Vegetation Type - Describes the vegetation type present. Newer structure will likely have only grasses planted along banks. Older structures can have grasses, several herbaceous species, as well as shrubs and tree saplings. Wetland vegetation on newer structures may not be present, but can consist of several types of algae, submerged and emergent aquatic species at older, more established structure.

Pond/Ditch Cover - Cover vegetation is evaluated in terms of provision of shading and escape cover for fish. A rating is obtained by visually determining the dominant vegetation type covering the exposed pond bottom, bank, and top of bank. Riparian vegetation dominated by shrubs and trees provides the CPOM source in allochthonous systems.

HABITAT RESULTS

Upstream Honey Branch Station (Toe of Valley Fill)

This station received excellent substrate and instream cover (primary) ratings, good to excellent channel morphology (secondary) ratings, and fair to excellent riparian and bank structure (tertiary) ratings. Overall, this upstream station on Honey Branch contained more than adequate food sources, flows, excellent habitat and cover, but was slightly limited by bank stability and the lack of deeper pools (Table 4A).

Middle Honey Branch Station

This station received excellent substrate and instream cover (primary) ratings, good to excellent channel morphology (secondary) ratings, and fair to excellent riparian and bank structure (tertiary) ratings. Overall, this station on Honey Branch contained adequate food sources, fine flows, good cover and bank stability, but was limited by the lack of better streamside cover and deeper pools (Table 4A).

Downstream Honey Branch (Mouth of Honey Branch)

This station received good to excellent substrate and instream cover (primary) ratings, good to excellent channel morphology (secondary) ratings, and good riparian and bank structure (tertiary) ratings. Overall, this station located at the mouth of Honey Branch contained adequate food sources, but was limited by deposition, bank stability, and streamside cover (Table 4A).

Upstream East Fork of Twelvepole Creek

This station received fair to excellent substrate and instream cover (primary) ratings, fair to excellent channel morphology (secondary) ratings, and good riparian and bank structure (tertiary) ratings. Overall, this station above the confluence with Honey Branch contained good habitat and adequate food sources, but was severely limited by the lack of riffle areas, bank stability, and the lack of adequate streamside cover (Table 4A).

Downstream East Fork of Twelvepole Creek

This station received excellent substrate and instream cover (primary) ratings, good to excellent channel morphology (secondary) ratings, and good riparian and bank structure (tertiary) ratings. Overall, this station below the confluence with Honey Branch contained good habitat and adequate food sources, but was limited by deposition, bank stability, and the lack of adequate streamside cover (Table 4A).

Honey Branch's Middle Pond (Number 2)

This pond had a surface area of 0.53 acres and was approximately 150 feet long by 150 feet wide (Table 4B). Because it was completed many few years ago in 1988, banks were 100% vegetated, and with grasses, herbaceous plants, shrubs, saplings, and larger trees. The substrate was silty, detrital material. This structure has fairly good storage potential, and it should serve well as a sediment control pond. Because banks are stable, this structure will most likely remain an open water pond for quite some time. This structure has good wetland potential, and due to its larger size, may serve very well for waterfowl, fish, and amphibians.

Honey Branch's Lower Pond (Number 1)

This pond had a surface area of 1.01 acres, and was approximately 500 feet long by 300 feet wide (Table 4B). Because it was completed many few years ago in 1988, banks were 100% vegetated, and with grasses, herbaceous plants, shrubs, saplings, and larger trees. The substrate was silty, detrital material. This structure has fairly good storage potential, and it should serve well as a sediment control pond. Because banks are fairly stable, this structure will most likely remain an open water pond for quite some time. This structure has tremendous wetland potential, and due to its large size, should serve very well for waterfowl, fish, and amphibians. In addition, due to its placement and surrounding settings, this structure has a very high aesthetic value.

Honey Branch Sediment Ditch

This sediment ditch had a surface area of 0.05 acres, and was approximately 100 feet long by 20 feet wide (Table 4B). Because it was completed many few years ago in 1988, banks were 100% vegetated, and with grasses, herbaceous plants, shrubs, saplings, and larger trees. The substrate was heavily organic, detrital material. This structure has some storage potential, but appears to be close to reaching its full potential. This structure has good wetland potential, even though it was small in size.

DESCRIPTION OF BENTHIC MACROINVERTEBRATE METRICS

Several benthic macroinvertebrate measurements were calculated (Tables 3A and 3B) for each of the stations sampled on Honey Branch, the East Fork of Twelvepole Creek, the Honey Branch sediment ponds and the sediment ditch on Honey Branch. The individual metrics are described below.

Metric 1. Taxa Richness - Reflects the health of the community through a measurement of the variety of taxa present. Generally increases with increasing water quality, habitat diversity, and habitat suitability. However, the majority should be distributed in the pollution sensitive groups, a lesser amount in the facultative groups, and the least amount in the tolerant groups. Polluted streams shift to tolerant dominated communities.

Metric 2. Modified Hilsenhoff Biotic Index - This index was developed by Hilsenhoff (1987) to summarize overall pollution tolerance of the benthic arthropod community with a single value. Calculated by summarizing the number in a given taxa multiplied by its tolerance value, then divided by the total number of organisms in the sample.

Metric 3. Ratio of Scraper and Filtering Collector Functional Feeding Groups - This ratio reflects the riffle/run community foodbase and provides insight into the nature of potential disturbance factors. The relative abundance of scrapers and filtering collectors indicate the periphyton community composition, availability of suspended Fine Particulate Organic Material (FPOM) and availability of attachment sites for filtering. Filtering collectors are sensitive to toxicants bound to fine particles and should be the first group to decrease when exposed to steady sources of bound toxicants.

Metric 4. Ratio of Ephemeroptera, Plecoptera, Trichoptera (EPT) and Chironomidae Abundances - This metric uses relative abundance of these indicator groups as a measure of community balance. Good biotic condition is reflected in communities having a fairly even distribution among all four major groups and with substantial representation in the sensitive groups Ephemeroptera, Plecoptera, and Trichoptera. Skewed populations with large amounts of Chironomidae in relation to the EPT indicates environmental stress.

Metric 5. Percent Contribution of Dominant Family - This is also a measure of community balance. A community dominated by relatively few species would indicate environmental stress. A healthy community is dominated by pollution sensitive representation in the Ephemeroptera, Plecoptera, and Trichoptera groups.

Metric 6. EPT Index - This index is the total number of distinct taxa within the Orders: Ephemeroptera, Plecoptera, and Trichoptera. The EPT Index generally increases with increasing water quality. The EPT index summarizes the taxa richness within the pollution sensitive insect orders.

Metric 7. Ratio of Shredder Functional Feeding Group and Total Number of Individuals Collected - Allows evaluation of potential impairment as indicated by the shredder community. Shredders are good indicators of riparian zone impacts.

Metric 8. Simpson's Diversity Index - This index ranges from 0 (low diversity) to almost 1 (high diversity). A healthy benthic macroinvertebrate community should have a higher Simpson's Diversity Index.

Metric 9. Shannon-Wiener Diversity Index - Measures the amount of order in the community by using the number of species and the number of individuals in each species. The value increases with the number of species in the community. A healthy benthic macroinvertebrate community should have a higher Shannon-Wiener Diversity Index.

Metric 10. Shannon-Wiener Evenness - Measures the evenness, or equitability of the community by scaling one of the heterogeneity measures relative to its maximal value when each species in the sample is represented by the same number of individuals. Ranges from 0 (low equitability) to 1 (high equitability).

BENTHIC MACROINVERTEBRATE RESULTS

Upstream Honey Branch Station (Toe of Valley Fill)

A total of 626 individuals comprising 22 taxa were collected (Tables 2A and 5). Five pollution sensitive (intolerant) taxa comprising 6.9% of the station's abundance were present. The sensitive mayfly Leptophlebia (Family: Leptophlebiidae) contributed 5.4% to the total abundance at this upstream station. Nine facultative (intermediate tolerance) taxa were present comprising 7.2% of the station's total abundance. The facultative springtail Collembola contributed 3.4% to the total abundance. Eight tolerant taxa were present comprising 85.9% of the abundance at this station. The tolerant aquatic worm, Oligochaeta, accounted for 51.1% of the total abundance, and was the most abundant taxa present at this station on Honey Branch. Ten EPT groups (Table 3A) were present which aided the EPT:Chironomidae Index in being fairly desirable. All functional feeding groups were present and were fairly well represented at this station. A very wide variety of stoneflies and caddisflies were collected at this station; mayflies were less abundant. The Simpson's and Shannon-Wiener Diversity indices reflected a moderately diverse community; the Shannon-Wiener Evenness value of 0.52 indicated that abundances were only moderately distributed among the taxa. The Modified Hilsenhoff Biotic Index (HBI) and the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) indicated a moderately healthy, but pollution tolerant macroinvertebrate community with a fairly good periphyton community composition.

Middle Honey Branch Station

A total of 558 individuals comprising 21 taxa were collected (Tables 2A and 6). Five pollution sensitive (intolerant) taxa comprising 18.3% of the station's abundance were present. The sensitive beetle Family: Elmidae contributed 14.0% to the total abundance at this Honey Branch station. Eight facultative (intermediate tolerance) taxa were present comprising 22.9% of the sample. The facultative stonefly Leuctra (Family: Leuctridae) contributed 10.0% to the total abundance. Eight tolerant taxa were present comprising 58.8% of the abundance at this station. Again, the tolerant aquatic worm, Oligochaeta, accounted for 30.0% of the total abundance, and was the most abundant taxa at this station on Honey Branch. Eight EPT groups (Table 3A) were present which contributed to the EPT:Chironomidae Index in being very desirable. All functional feeding groups were present and were very well represented. A wide variety of stoneflies and caddisflies were collected at this station; mayfly population was again low. The Simpson's and Shannon-Wiener Diversity indices reflected a very diverse community, and the Shannon-Wiener Evenness indicated that abundances were moderately well distributed among the taxa. The Modified Hilsenhoff Biotic Index (HBI) and the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) indicated a more balanced and less tolerant community than the upstream station.

Downstream Honey Branch Station (Mouth of Honey Branch)

A total of 306 individuals comprising 19 taxa were collected (Tables 2A and 7). Five pollution sensitive (intolerant) taxa comprising 10.8% of the station's abundance were present. The sensitive caddisfly Family: Philopotamiidae contributed 5.2% to the total abundance at this station. Seven facultative (intermediate tolerance) taxa were present comprising 20.6% of the sample. The facultative caddisfly Family: Hydropsychidae accounted for 8.5% of the station's abundance. Seven tolerant taxa were present comprising 68.6% of the abundance at this station at the Mouth of Honey Branch. The tolerant midge, Chironomidae, accounted for 28.1% of the total abundance, and was the most abundant taxa of aquatic insect present. Nine EPT groups (Table 3A) were present which again aided the EPT:Chironomidae Index in being very desirable. All functional feeding groups were present and were well represented. A wide variety of mayflies, stoneflies, and caddisflies were collected at this station. The Simpson's and Shannon-Wiener Diversity Indices reflected a community moderately-high in diversity, and the Shannon-Wiener Evenness indicated that abundances were well distributed among the taxa, or heterogeneous. The Modified Hilsenhoff Biotic Index (HBI) and the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) indicated a pollution tolerant, but healthy macroinvertebrate community with a very good periphyton community composition.

<u>Upstream East Fork of Twelvepole Creek</u>

A total of 1,800 individuals comprising 18 taxa were collected (Tables 2A and 8). Five pollution sensitive (intolerant) taxa comprising 37.6% of the station's abundance were present. The sensitive beetle Family: Elmidae contributed 15.8% to the total abundance at this station on the East Fork of Twelvepole Creek. Nine facultative (intermediate tolerance) taxa were present comprising 17.8% of the sample. The facultative mayfly Isonychia (Family: Oligoneuridae) accounted for 5.8% of the station's abundance, and was a significant contributor to the station. Four tolerant taxa were present comprising 44.7% of the abundance at this station above the confluence with Honey Branch. The tolerant midge, Chironomidae, accounted for 27.6% of the total abundance, and was once again the most abundant Family of aquatic insect present. Ten EPT groups (Table 3A) were present which again aided the EPT:Chironomidae Index in being very desirable. All functional feeding groups were present and were very well represented. Again, a wide variety of mayflies, stoneflies, and caddisflies were collected at this station. The Simpson's and Shannon-Wiener Diversity Indices reflected a community moderately-high in diversity; the Shannon-Wiener Evenness indicated that abundances were moderately well distributed among the taxa, or heterogeneous. The Modified Hilsenhoff Biotic Index (HBI) and the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) indicated a slightly unbalanced, but healthy macroinvertebrate community.

<u>Downstream East Fork of Twelvepole Creek</u>

A total of 1,244 individuals comprising 14 taxa were collected (Tables 2A and 9). Five pollution sensitive (intolerant) taxa comprising 31.8% of the station's abundance were present. The sensitive mayfly Stenonema (Family: Heptageniidae) contributed 10.5% to the total abundance at this station on the East Fork of Twelvepole Creek. Only two facultative (intermediate tolerance) taxa were present comprising 3.5% of the sample. The facultative caddisfly Family: Hydropsychidae accounted for 2.6% of the station's abundance. Seven tolerant taxa were present comprising 64.7% of the abundance at this station below the confluence with Honey Branch. The tolerant midge, Chironomidae, accounted for 53.4% of the total abundance, and was once again the most abundant Family of aquatic insect present. Five EPT groups (Table 3A) were present which again aided the EPT:Chironomidae Index in being moderately desirable. All functional feeding groups were present and were very well represented. A wide variety of mayflies were collected at this station; stoneflies and caddisflies were not very well represented. The Simpson's and Shannon-Wiener Diversity Indices reflected a community with moderate diversity; the Shannon-Wiener Evenness indicated that abundances were moderately distributed among the taxa. The Modified Hilsenhoff Biotic Index (HBI) and the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) indicated a somewhat unbalanced, but fairly healthy macroinvertebrate community.

Honey Branch's Middle Pond (Number 2)

A total of 2,720 individuals comprising 9 taxa were collected (Tables 2B and 10). Only one pollution sensitive (intolerant) taxa was present, the mayfly, Ephemera (Family: Ephemeridae), which contributed 1.2% to the total abundance of this pond. Two facultative (intermediate tolerance) taxa were present comprising 7.1% of the sample. The facultative mayfly Baetis (Family: Baetidae) accounted for 4.7% of the site's abundance, and was a significant component to the site's community. Six tolerant taxa were present comprising 91.7% of the abundance at this site. The tolerant midge, Chironomidae, accounted for 55.9% of the total abundance, and was the most abundant taxa at this middle sediment pond on Honey Branch. Three EPT groups (Table 3B) were present which contributed to the EPT:Chironomidae Index in being fairly desirable. Again, no scrapers or collector/filterers were present, however, a moderate variety of mayflies were collected at this station. The Simpson's and Shannon-Wiener Diversity indices reflected a community moderately-low in diversity, and the Shannon-Wiener Evenness indicated that abundances were moderately distributed among the taxa. The Modified Hilsenhoff Biotic Index (HBI) and the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) indicated a very pollution tolerant benthic macroinvertebrate community.

Honey Branch's Lower Pond (Number 1)

A total of 1,392 individuals comprising 8 taxa were collected (Tables 2B and 11). No pollution sensitive (intolerant) taxa were present. Three facultative (intermediate tolerance) taxa were present comprising 13.8% of the sample. The facultative mayfly Caenis (Family: Caenidae) accounted for 9.2% of the site's abundance, and was a significant component to the site's community. Five tolerant taxa were present comprising 86.2% of the abundance at this site. The tolerant midge, Chironomidae, accounted for 49.4% of the total abundance, and was the most abundant taxa at this lower sediment control pond on Honey Branch. One EPT group (Table 3B) was present which helped to contribute to the EPT:Chironomidae Index. Again, no scrapers or collector/filterers were present. Not a wide variety of mayflies were collected at this station (Caenis was the only taxa). The Simpson's and Shannon-Wiener Diversity indices reflected a community moderately-low in diversity, and the Shannon-Wiener Evenness indicated that abundances were moderately distributed among the taxa. The Modified Hilsenhoff Biotic Index (HBI) and the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) indicated a very pollution tolerant benthic macroinvertebrate community.

Honey Branch's Sediment Ditch

A total of 2,192 individuals comprising 8 taxa were collected (Tables 2B and 12). Only one pollution sensitive (intolerant) taxa was present, the beetle, Peltodytes (Family: Haliplidae), which contributed 1.6% to the total abundance of this sediment ditch. Two facultative (intermediate tolerance) taxa were present comprising 13.1% of the sample. The facultative mayfly Baetis (Family: Baetidae) accounted for 12.4% of the site's abundance, and was a significant component to the site's community. Five tolerant taxa were present comprising 85.3% of the abundance at this site. The tolerant midge, Chironomidae, accounted for 37.2% of the total abundance, and was the most abundant taxa at this sediment ditch on Honey Branch. One EPT group (Table 3B) was present which contributed to the EPT:Chironomidae Index in being fairly desirable. Again, no scrapers or collector/filterers were present, and only the one taxa of mayflies was collected at this station. The Simpson's and Shannon-Wiener Diversity indices reflected a community with moderate diversity, and the Shannon-Wiener Evenness indicated that abundances were moderately-well distributed among the taxa. The Modified Hilsenhoff Biotic Index (HBI) and the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) indicated a pollution tolerant/facultative benthic macroinvertebrate community.

DISCUSSION

One-way analysis of variance (ANOVA) comparing the abundances of aquatic macroinvertebrates between the three stations sampled on Honey Branch concluded that abundances between the three sites were not statistically significantly (? = 0.05) different (F value = 1.82). In addition, a one-way ANOVA comparing the number of taxa of aquatic macroinvertebrates between the three stations on Honey Branch also concluded that there was no significant difference in the number of taxa collected between the three stations.

When comparing total abundances between these three stations sampled on Honey Branch (Table 2A), it is somewhat apparent that differences exist. As stated previously, these differences were not statistically different. The Upstream Station (Toe of the Valley Fill) contained the largest total abundance as well as a couple more taxa than the Middle and Downstream (Mouth) Stations. Habitat (Table 4A) was very generally excellent and also very similar between the three Honey Branch sites with the exception of bank stability and streamside cover, but these parameters were not limiting to the aquatic fauna. Water chemistry (Table 1A) was overall fairly desirable, but the stations on Honey Branch did have elevated levels of sulfates, hardness, dissolved solids, and some metals, although these levels were not considered too limiting as several sensitive taxa comprised of many individuals were collected. Influence from the sediment ponds located on Honey Branch was also not limiting to the stream macroinvertebrate populations as the Upstream Honey Branch station (above the sediment ponds) did not have significantly more desirable aquatic insect populations than the Downstream Honey Branch station which was located below all sediment ponds and valley fills. The Downstream site did have lower total abundances of aquatic insects, but percentages of sensitive and facultative groups actually increased at the downstream station compared to the upstream station. It is also very interesting to note that the total disturbed area of the Honey Branch watershed is 261.69 acres or 43% of the total watershed area. Because this is now considered to be a high percentage of total disturbed area within a watershed, one would expect that the Honey Branch stream stations would have had poorer macroinvertebrate communities. However, the three stations located on Honey Branch contained relatively healthy populations of aquatic insects. This is based on the macroinvertebrate data which depicted that many individuals were collected from a very large number of taxa. Samples were comprised of many EPT groups and individuals (Table 3A), and all functional feeding groups were present and were generally well represented. It is obvious that the loss of a portion of the headwater area of Honey Branch from valley fills has not eliminated nor negatively affected the macroinvertebrate community downstream as originally believed.

One-way analysis of variance (ANOVA) comparing the abundances of aquatic macroinvertebrates between the two stations sampled on the East Fork of Twelvepole Creek concluded that abundances between the two sites were not statistically significantly (? = 0.05) different (F value = 1.06). In addition, a one-way ANOVA comparing the number of taxa of aquatic macroinvertebrates between the two stations also concluded that there was no significant difference in the number of taxa collected between the two sites on the East Fork of Twelvepole Creek. This observation is crucial, because it exemplifies that the discharge from Honey Branch is not having a negative impact on the aquatic insect abundances located on the East Fork of Twelvepole Creek.

When comparing total abundances and taxa between these two stations sampled on the East Fork of Twelvepole Creek (Table 2A), one can observe that a few differences exist. As stated previously, these differences were not statistically different. From the water chemistry data (Table 1A), one can observe that overall water quality at both the East Fork of Twelvepole Creek's stations was desirable with near neutral pH levels, desirable alkalinity, and low conductivity, acidity, hardness, solids, sulfates, and most metals. In general, the downstream station on the East Fork of Twelvepole Creek had higher levels of most chemical constituents, but none were considered limiting to the aquatic fauna. These higher levels was obviously from the discharge of Honey Branch. From the habitat data (Table 4A), the downstream station on the East Fork had more desirable substrates as well as a better representation of riffle areas. There was, however, a shift in the community from one comprised of fairly equal percentages of sensitive and tolerant individuals at the upstream station, to one comprised of many more tolerant than sensitive individuals at the downstream station. This shift is undoubtably a factor of the water chemistry from Honey Branch. Although total abundances and total taxa are not significantly affected from the discharge, the water chemistry is affecting the composition of the macroinvertebrate community downstream. Nevertheless, both of the East Fork of Twelvepole Creek stations were considered healthy because they were comprised of a large number of taxa consisting of large abundances of aquatic insects. They both contained large numbers of sensitive individuals from several taxa. Both stations also contained wide varieties and large abundances of mayflies, stoneflies, and caddisflies (Table 3A).

The two stations located on the East Fork of Twelvepole Creek were not statistically compared to the stations located on Honey Branch because the streams represent different order (size) streams (the East Fork of Twelvepole Creek is at least 3rd order at the confluence with Honey Branch; Honey Branch is 1st order). With different order or stream sizes comes automatic differences in habitat (Table 4A), water quality/chemistry (Table 1A), and benthic macroinvertebrate communities (Table 2A).

The two ponds studied on Honey Branch (Pond Number 2 and Pond Number 1) contained large and low total numbers of aquatic insects, respectively. They both, however, contained relatively low numbers of taxa even though they were the older, more established structures (completion dates in 1988). This may have been due to the somewhat high pH levels, the more alkaline waters, or the elevated sulfates, magnesium, and/or chloride levels. The sediment ditch on Honey Branch contained a relatively large abundance of aquatic insects as well as a moderate number of taxa. No single chemical parameter or habitat parameter appeared limiting with the exception of the low dissolved oxygen level of 2.57 (Table 1B).

In general, the ponds and sediment control ditch on Honey Branch were well represented by the groups of aquatic insects which are normally present in these lentic type habitats. The functional feeding groups scrapers and collector/filterers were not present (Table 3B), but this was not surprising since scrapers need silt-free environments for them to feed on the periphyton that attaches to rock substrates, and since the collector/filterers require faster-moving water in order to feed on the small particles of food which collected on constructed silken nets or on hairs on their bodies. The shredder functional feeding group (those that shred and consume leaves and other detrital materials) was also not well represented, but this group is also considered to be sensitive to disturbances and pollution. Generally, the sites were comprised mostly of tolerant organisms such as midges, dragonflies, and aquatic worms (Table 2B). As stated previously, this was to be expected, and was representative of aquatic insects which thrive in pond-type habitats.

If constructed properly, these sediment control ponds and sediment ditches can do a splendid job in removing solids and other water contaminants both by filtration and by precipitation prior to reaching downstream areas. They also provide aquatic habitats for countless abundances of aquatic insects, amphibians, reptiles, waterfowl, terrestrial wildlife, and potentially even fish. It should be pointed out that prior to mining, there was very little wetland habitat available on Honey Branch. Now, with the construction of the three sediment control ponds and the sediment ditch, several acres of open water as well as the subsequent wetland areas surrounding each pond and the sediment ditch have been added to the area. In addition, prior to mining, Honey Branch consisted of about 1,500 feet of intermittent stream. Now, there is approximately 1-2 miles of drainage ditches and main stream channel present, and but with the ponds available, total water surface area is considerably greater. The ponds studied for this report, undoubtably, provide an additional facet to the aquatic and semi-aquatic fauna currently found in area.

These sedimentation ponds can easily be converted into aesthetic, attractive, and usable wildlife features with very few modifications. For example, trees felled into the pond add both food and habitat for many species of aquatic insects. Additional structures can be placed in the ponds to provide hiding habitat for lentic fish species such as sunfish and bass. These structures also provide a refuge for both fish and insects, act as a breeding ground for many species of insects as well as some fish. Although prohibited from planting permanent, larger-growing vegetation such as trees around structures which are considered temporary, changes in management design could take place if these structures were to be considered as a permanent, and additional habitat for the area. Tall grasses, shrubs, and willow saplings, as well as larger trees could then be planted surrounding the pond to provide both a food source from fallen leaves/sticks and shade along shoreline areas.

If one compares this study to the previous conducted studies, several comparisons can be made. At the Upstream Honey Branch site (Toe of the Valley fill), during the SAIC Study (1998), only 41 organisms were collected from six taxa. Twenty-nine were isopods, leaving only 12 listed as being in the Class Insecta. There were seven EPT individuals from two taxa. During the Heer, Inc. sampling (1987), only six organisms from four taxa were collected. There were no common taxa present between the 1987 or 1998 studies. From Table 2A, during the current study, there were 626 individuals from 22 taxa collected. At the Middle Honey Branch site, during the SAIC Study, 172 individuals from 14 taxa (6 EPT taxa) were collected. During the Heer, Inc. Study, no organisms were collected at this site. From Table 2A, there were 558 individuals from 21 taxa (8 EPT taxa) collected. At the Downstream Honey Branch site (Mouth of Honey Branch), during the 1998 SAIC Study, 154 individuals from eleven taxa (4 EPT taxa) were collected. During the 1987 Heer, Inc. Study, 22 individuals from seven taxa (4 EPT taxa) were collected at the mouth of Honey Branch. During the current study, 306 individuals from 19 taxa (including 9 EPT taxa) were collected (Tables 2A and 3A). At the Downstream East Fork of Twelvepole Creek station, during the SAIC Study, 154 individuals from 16 taxa (9 EPT taxa) were collected. During the Heer, Inc. Study, 15 organisms from 6 taxa (1 EPT taxa) were collected. From this current study, 1,244 individuals from 14 taxa (5 EPT taxa) were collected at the downstream station on the East Fork of Twelvepole Creek.

Presumably, no upstream station on the East Fork of Twelvepole Creek was sampled during the SAIC and the Heer, Inc. Studies. Therefore, no determination on possible effects on East Fork's downstream station from Honey Branch's discharge could not be made. From the water chemistry data from the SAIC Study, iron levels are very similar; manganese levels have increased at the Upstream and Middle Honey Branch sites; TSS levels are similar; chloride levels are similar on Honey Branch, but have increased on the East Fork of Twelvepole Creek; magnesium levels are similar on Honey Branch, but have increased on the East Fork of Twelvepole Creek; calcium levels are similar on Honey Branch, but have increased on the East Fork of Twelvepole Creek; and sodium levels have increased at all sites. Most of these increases are most likely not significant, and are believed to be non-limiting as overall benthic macroinvertebrate results have become more desirable since the 1998 study. Even though overall tolerance levels determined for the current study depict more tolerant communities at each site than depicted from the previous studies, caution should be used here since the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) were based on much smaller total numbers of individuals and very few taxa.

CONCLUSIONS

Influence from the sediment ponds located on Honey Branch was also not limiting to the stream macroinvertebrate populations as the Upstream Honey Branch station (above the sediment ponds) did not have significantly more desirable aquatic insect populations than the Downstream Honey Branch station which was located below all sediment ponds and valley fills. The Downstream site did have lower total abundances of aquatic insects, but percentages of sensitive and facultative groups actually increased at the downstream station compared to the upstream station. It is also very interesting to note that the total disturbed area of the Honey Branch watershed is 261.69 acres or 43% of the total watershed area. Because this is now considered to be a high percentage of total disturbed area within a watershed, one would expect that the Honey Branch stream stations would have had poorer macroinvertebrate communities. However, the three stations located on Honey Branch contained relatively healthy populations of aquatic insects. This is based on the macroinvertebrate data which depicted that many individuals were collected from a very large number of taxa. The stations contained a wide variety of stoneflies, mayflies, and caddisflies, and were represented by all functional feeding groups. Of the physical and chemical water quality parameters analyzed at the Honey Branch locations, none were considered too limiting, although several were considered to be elevated. Food inputs were readily available, and habitat was considered excellent at each location due to the surrounding forest, which obviously contributed to the desirable aquatic macroinvertebrate communities inhabiting Honey Branch. It is obvious that the loss of a portion of the headwater area of Honey Branch from valley fills has not eliminated nor negatively affected the macroinvertebrate community downstream as originally believed.

Overall, the benthic macroinvertebrate populations found at the two stations located on the East Fork of Twelvepole Creek were considered to be healthy because they were comprised of communities containing a very wide variety of taxa and very large abundances of individuals. They also were comprised of many sensitive and facultative individuals represented by several taxa. Both stations contained a wide variety of mayflies; stoneflies and caddisflies were less represented at the downstream East Fork station. All functional feeding groups were present and were well represented at both stations. Of the physical and chemical water quality parameters analyzed at both locations, none were considered limiting, although the effects from Honey Branch entering the East Fork of Twelvepole Creek were observable in the water chemistry data. There was also a shift towards a more tolerant community at the downstream East Fork station. Nevertheless, both stations contained desirable benthic macroinvertebrate communities which was a result of the good water quality, desirable habitat, and available food inputs.

In general, the ponds and sediment control ditch on Honey Branch were well represented by the groups of aquatic insects which are normally present in these lentic type habitats. The functional feeding groups scrapers and collector/filterers were not present, but this was not surprising since scrapers need silt-free environments for them to feed on the periphyton that attaches to rock substrates, and since the collector/filterers require faster-moving water in order to feed on the small particles of food which collected on constructed silken nets or on hairs on their bodies. The shredder functional feeding group (those that shred and consume leaves and other detrital materials) was also not well represented, but this group is also considered to be sensitive to disturbances and pollution. Generally, the sites were comprised mostly of tolerant organisms such as midges, dragonflies, and aquatic worms. As stated previously, this was to be expected, and was representative of aquatic insects which thrive in pond-type habitats.

Much greater abundances as well as more taxa of aquatic insects were collected during this study compared to previous studies conducted at the same locations. Some of the levels of water chemistry constituents have remained similar; others have increased, but not to limiting levels, and mostly on the East Fork of Twelvepole Creek. Some shifts towards more tolerant communities may have occurred since the previous studies, but caution should be used since the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) were based on much smaller total numbers of individuals and very few taxa.

APPENDIX A

APPENDIX B

TABLE 1A. Physical and chemical water-quality variables for stream stations on Honey Branch and on Twelvepole Creek, above and below confluence with Honey Branch, 08 October 1999.

PARAMETER	Upstream Honey Branch	Midstream Honey Branch	Mouth Honey Branch	Upstream Twelvepole Creek	Downstream Twelvepole Creek
Flow (ft^3/s)	0.15	0.08	0.11	0.11	0.21
Temperature (?C)	13.36	14.41	16.29	13.88	14.77
Dissolved Oxygen (mg/l)	6.82	7.74	6.64	4.69	6.56
pH (SI units)	6.60	7.91	7.92	7.16	7.50
Conductivity (? mhos)	400	367	348	159	212
Acidity (mg/l)	<1.0	<1.0	<1.0	<1.0	<1.0
Alkalinity (mg/l)	138	126	123	85.1	93.7
Chloride (mg/l)	3.5	3.8	3.5	12.0	9.3
Hardness (mg/l)	303	284	267	87	137
Sulfate (mg/l)	188	167	152	28.2	66.3
TDS (mg/l)	412	418	358	166	218
TSS (mg/l)	3	2	3	14	6
Fecal Coliform (#/100ml)	23	14	4	150	110
Aluminum (mg/l)	0.109	0.116	0.076	0.130	0.102
Antimony (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic (mg/l)	0.002	<0.002	<0.002	0.003	<0.002
Barium (mg/l)	0.033	0.030	0.040	0.045	0.043
Beryllium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium (mg/l)	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Calcium (mg/l)	53.4	49.6	48.1	20.9	28.9
Chromium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005
Iron (mg/l)	0.370	0.358	0.060	0.481	0.316
Lead (mg/l)	<0.002	<0.002	<0.002	<0.002	<0.002
Magnesium (mg/l)	41.2	38.8	35.7	8.46	15.7
Manganese (mg/l)	0.255	0.139	0.026	0.068	0.046
Mercury (mg/l)	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel (mg/l)	<0.030	<0.030	<0.030	<0.030	<0.030
Selenium (mg/l)	<0.003	<0.003	<0.003	<0.003	<0.003
Silver (mg/l)	<0.004	<0.004	<0.004	<0.004	<0.004
Sodium (mg/l)	7.86	7.35	6.88	10.7	9.95
Thallium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc (mg/l)	0.004	0.009	0.003	0.016	<0.002

TABLE 1B. Physical and chemical water-quality variables for Honey Branch sediment control ponds and ditch, 08 October 1999.

PARAMETER	Middle Honey Branch Pond (1988)	Lower Honey Branch Pond (1988)	Honey Branch Sediment Ditch (1988)
Temperature (?C)	11.83	16.71	11.29
Dissolved Oxygen (mg/l)	10.34	7.25	2.57
BOD (mg/l)	<2	<2	3
pH (SI units)	8.19	7.87	6.67
Conductivity (?mhos)	357	342	450
Acidity (mg/l)	<1.0	<1.0	<1.0
Alkalinity (mg/l)	122	121	94.6
Chloride (mg/l)	3.9	3.8	2.4
Hardness (mg/l)	280	268	349
Sulfate (mg/l)	167	161	274
TDS (mg/l)	324	381	501
TSS (mg/l)	3	<1	11
Fecal Coliform (#/100ml)	105	6	9
Aluminum (mg/l)	0.064	0.125	0.070
Antimony (mg/l)	<0.001	<0.001	<0.001
Arsenic (mg/l)	<0.002	<0.002	<0.002
Barium (mg/l)	0.028	0.035	0.019
Beryllium (mg/l)	<0.001	<0.001	<0.001
Cadmium (mg/l)	<0.0003	<0.0003	<0.0003
Calcium (mg/l)	49.1	47.3	68.2
Chromium (mg/l)	<0.001	<0.001	<0.001
Copper (mg/l)	<0.005	0.012	<0.005
Iron (mg/l)	0.307	0.275	0.130
Lead (mg/l)	<0.002	<0.002	<0.002
Magnesium (mg/l)	38.3	36.3	43.4
Manganese (mg/l)	0.154	0.126	0.165
Mercury (mg/l)	<0.0002	<0.0002	<0.0002
Nickel (mg/l)	<0.030	<0.030	<0.030
Selenium (mg/l)	<0.003	<0.003	<0.003
Silver (mg/l)	<0.004	<0.004	<0.004
Sodium (mg/l)	8.06	7.78	8.98
Thallium (mg/l)	<0.001	<0.001	<0.001
Zinc (mg/l)	<0.002	0.010	0.002

TABLE 2A. Total abundances of benthic macroinvertebrates collected via Surber and Kick-net samples from stream stations on Honey Branch and Twelvepole Creek, above and below confluence with Honey Branch, 08 October 1999.

	STATION				
TAXON	Upstream Honey Branch	Midstream Honey Branch	Mouth Honey Branch	Upstream Twelvepole Creek	Downstream Twelvepole Creek
Insecta					
Ephemeroptera (Mayflies)					
Ameletidae					
Ameletus (F)		8	12		
Baetidae					
Baetis (F)				36	
Baetiscidae					
Baetisca (S)				68	126
Caenidae					
Caenis (S)				76	30
Ephemerellidae					
Ephemerella (F)			2	12	
Heptageniidae					
Stenonema (S)			1	244	130
Leptophlebiidae					
Leptophlebia (S)	34				
Oligoneuridae					
Isonychia (F)				104	
Plecoptera (Stoneflies)					
Capniidae (S)			2		8
Chloroperlidae (S)	4	4	6		
Leuctridae					
Leuctra (F)	2	56	4	36	
Perlidae (S)	1				
Perlodidae (F)	3	12			
Taeniopterygidae (F)	2			16	
Trichoptera (Caddisflies)					
Hydropsychidae (F)	2	26	26	88	32
Lepidostomatidae					
Lepidostoma (S)	2				
Limnephilidae (F)		4			
Philopotamiidae (S)		16	16		
Polycentropodidae (F)	8	4	2		
Rhyacophilidae (F)	4			4	

TABLE 2A. Continued.

TAXON	Upstream Honey Branch	Midstream Honey Branch	Mouth Honey Branch	Upstream Twelvepole Creek	Downstream Twelvepole Creek
	STATION				
Diptera (True Flies)					
Ceratopogonidae (T)	38	8		28	24
Chaoboridae (T)		2			
Chironomidae (T)	148	148	86	496	664
Simuliidae (F)		4		20	
Stratiomyidae (T)		2			
Tabanidae (T)	8				
Tipulidae					
Dicranota (T)		2			
Hexatoma (T)	16			4	
Tipula (T)		2	4		2
Coleoptera (Beetles)					
Elmidae (S)	1	78	8	284	102
Psephenidae (S)				4	
Saldidae (S)	1	2			
Hemiptera (Water Bugs)					
Corixidae (T)	2				
Odonata (Dragonflies)					
Coenagrionidae (T)_					2
Cordulegastridae					
Cordulegaster (T)					5
Gomphidae (T)	2		13		
Hagenius (T)			16		
Lanthus (T)			20		
Megaloptera (Hellgrammites)					
Corydalidae					
Corydalus (S)		2			
Collembola (Springtails) (F)	22	2	2		
Oligochaeta (Aquatic Worms) (T)	320	156	69	276	104
Planaridae (Flatworms) (T)	4	8	2		4
Crayfish (F)	2	12	15	4	11

TABLE 2A. Continued.

TAXON	STATION Upstream Honey Branch	Midstream Honey Branch	Mouth Honey Branch	Upstream Twelvepole Creek	Downstream Twelvepole Creek
salamander larvae* (U)	1				
clams* (U)				16	16
snails* (U)				4	
Johnny darter* (U)				1	
Total Individuals	626	558	306	1,800	1,244
Taxa	22	21	19	18	14
Sensitive Ind. (%)	43 (6.9)	102 (18.3)	33 (10.8)	676 (37.6)	396 (31.8)
Sensitive Taxa	5	5	5	5	5
Facultative Ind. (%)	45 (7.2)	128 (22.9)	63 (20.6)	320 (17.8)	43 (3.5)
Facultative Taxa	9	8	7	9	2
Tolerant Ind. (%)	538 (85.9)	328 (58.8)	210 (68.6)	804 (44.7)	805 (64.7)
Tolerant Taxa	8	8	7	4	7

* = Not included in abundance or taxa calculations. For observation only.

( ) Classification of Pollution Indicator Organisms
(S) = Sensitive (F) = Facultative (T) = Tolerant (U) = Unclassified

TABLE 2B. Total abundances of benthic macroinvertebrates collected via Ponar grab samples taken from Honey Branch sediment control ponds and sediment ditch at the Pen Coal Corporation, 08 October 1999.

TAXON	Middle Honey Branch Pond (1988)	Lower Honey Branch Pond (1988)	Honey Branch Sediment Ditch (1988)
Insecta			
Ephemeroptera (Mayflies)			
Baetidae			
Baetis (F)	128		272
Caenidae			
Caenis (F)	64	128	
Ephemeridae			
Hexagenia (S)	32		
Diptera (True Flies)			
Ceratopogonidae (T)	624	384	800
Chironomidae (T)	1520	688	816
Tipulidae			
Tipula (T)	32		
Coleoptera (Beetles)			
Dytiscidae (T)			16
Haliplidae			
Peltodytes (T)			32
Odonata (Dragonflies)			
Coenagrionidae (T)	16	16	48
Corduliidae			
Cordulia (T)	16	16	
Collembola (F)		48	16
Oligochaeta (Aquatic worms) (T)	288	96	192
Crayfish (F)		16	
clams* (U)	16	208	
Total Individuals	2,720	1,392	2,192
Total Taxa	9	8	8

TABLE 2B. Continued

	Middle Honey Branch Pond (1988)	Lower Honey Branch Pond (1988)	Honey Branch Sediment Ditch (1988)
Sensitive Ind. (%)	32 (1.2)	0 (0.0)	32 (1.6)
Number of Taxa	1	0	1
Facultative Ind. (%)	192 (7.1)	192 (13.8)	288 (13.1)
Number of Taxa	2	3	2
Tolerant Ind. (%)	2,496 (91.7)	1,200 (86.2)	1,872 (85.3)
Number of Taxa	6	5	5

* = Not included in abundance or taxa calculations. For observation only.

( ) Classification of Pollution Indicator Organisms
(S) = Sensitive (F) = Facultative (T) = Tolerant (U) = Unclassified

TABLE 3A. Selected benthic macroinvertebrate metrics for stations on Honey Branch and stations on Twelvepole Creek, above and below confluence with Honey Branch, 08 October 1999.

METRIC	Upstream Honey Branch	Midstream Honey Branch	Mouth Honey Branch	Upstream Twelvepole Creek	Downstream Twelvepole Creek
Taxa Richness	22	21	19	18	14
Modified Hilsenhoff Biotic Index	5.46	4.77	4.57	4.76	5.26
Ratio of Scrapers to Collector/Filterers	2:2	80:46	9:42	532:212	232:32
Ratio of EPT:Chironomidae	62:148	130:148	71:86	684:496	326:664
% Contribution of Dominant Family	51.1% Oligochaeta	30.0% Oligochaeta	28.1% Chironomidae	27.6% Chironomidae	53.4% Chironomidae
EPT Index	10	8	9	10	5
% Shredders to Total	5.4%	13.3%	4.6%	2.9%	0.6%
Simpson's Diversity Index	0.67	0.82	0.85	0.85	0.68
Shannon-Wiener Diversity	2.33	3.01	3.27	3.14	2.32
Shannon-Wiener Evenness	0.52	0.68	0.77	0.75	0.61

TABLE 3B. Selected benthic macroinvertebrate metrics for the Honey Branch sediment control ponds and sediment ditch located at the Pen Coal Corporation, 08 October 1999.

METRIC	Middle Honey Branch Pond (1988)	Lower Honey Branch Pond (1988)	Honey Branch Sediment Ditch (1988)
Taxa Richness	9	8	8
Modified Hilsenhoff Biotic Index	6.06	6.11	5.82
Ratio of Scrapers to Collector/Filterers	0:0	0:0	0:0
Ratio of EPT:Chironomidae	224:1520	128:688	272:816
% Contribution of Dominant Family	55.9% Chiro.[1]	49.4% Chiro.[1]	37.2% Chiro.[1]
EPT Index	3	1	1
% Shredders to Total	0.0%	3.4%	0.7%
Simpson's Diversity Index	0.63	0.66	0.70
Shannon-Wiener Diversity	1.91	1.99	2.06
Shannon-Wiener Evenness	0.58	0.66	0.69

1 = Diptera: Chironomidae

TABLE 4A. Habitat scores for the stations on Honey Branch and stations on Twelvepole Creek, above and below confluence with Honey Branch, 08 October 1999.

	Upstream Honey Branch	Midstream Honey Branch	Mouth Honey Branch	Upstream Twelvepole Creek	Downstream Twelvepole Creek
Primary - Substrate and Instream Cover					
1. Bottom Substrate and Available Cover (0-20)	18	18	18	14	17
2. Embeddedness (0-20)	18	19	16	16	17
3. Flow/Velocity (0-20)	16	18	18	10	16
Secondary - Channel Morphology					
4. Channel Alterations (0 - 15)	12	14	10	14	12
5. Bottom Scouring and Deposition (0 - 15)	12	14	11	13	10
6. Pool/Riffle, Run/Bend Ratio (0 -15)	11	11	14	7	12
Tertiary - Riparian and Bank Structure					
7. Bank Stability (0 -10)	5	10	7	6	7
8. Bank Vegetation Stability (0 -10)	9	10	7	7	7
9. Streamside Cover (0 - 10)	8	5	6	7	7

Note: The scoring for each category	Excellent	Good	Fair	Poor
Primary	16 - 20	11 - 15	6 - 10	0 - 5
Secondary	12 - 15	8 - 11	4 - 7	0 - 3
Tertiary	9 - 10	6 - 8	3 - 5	0 - 2

TABLE 4B. Summary of habitat descriptions for the Honey Branch sediment control ponds and sediment ditch located at the Pen Coal Corporation, 08 October 1999.

	Middle Honey Branch Pond (1988)	Lower Honey Branch Pond (1988)	Honey Branch Sediment Ditch (1988)
Pond/Ditch Surface Acreage			
	0.53	1.01	0.05
Length x Width (feet)			
	150 X 150	500 X 300	100 X 20
Bottom Substrate Type			
	silty, detrital	silty, detrital	all organic
Bank Stability			
	stable	fairly stable	very stable
Bank Vegetation Stability			
	100% vegetated	100% vegetated	100% vegetated
Vegetation Types			
	grasses, shrubs, herbaceous plants, filamentous algae, submerged & emergent aquatics	grasses, shrubs, herbaceous plants, filamentous algae, submerged & emergent aquatics	grasses, shrubs, herbaceous plants, filamentous algae, submerged & emergent aquatics
Pond/Ditch Cover			
	some	none	some

TABLE 5. Abundances of benthic macroinvertebrates collected per sample from the Upstream Honey Branch Station, Toe of the Valley Fill, 08 October 1999.

TAXON	SAMPLE Surber 1	Surber 2	Surber 3	Kick
Insecta				
Ephemeroptera (Mayflies)				
Leptophlebiidae				
Leptophlebia (S)				34
Plecoptera (Stoneflies)				
Chloroperlidae (S)	4			
Leuctridae				
Leuctra (F)	2			
Perlidae (S)	1			
Perlodidae (F)	1			2
Taeniopterygidae (F)	2			
Trichoptera (Caddisflies)				
Hydropsychidae (F)	2			
Lepidostomatidae				
Lepidostoma (S)			2	
Polycentropodidae (F)		4		4
Rhyacophilidae (F)			4	
Diptera (True Flies)				
Ceratopogonidae (T)	2		4	32
Chironomidae (T)	12	40	24	72
Tabanidae (T)		4		4
Tipulidae				
Hexatoma (T)	2	8	4	2
Coleoptera (Beetles)				
Elmidae (S)	1			
Saldidae (S)	1			
Hemiptera (Water Bugs)				
Corixidae (T)				2
Odonata (Dragonflies)				
Gomphidae (T)				2
Collembola (Springtails) (F)	2	8	8	4
Oligochaeta (Aquatic Worms) (T)	28	204	64	24

TABLE 5. Continued.

	SAMPLE			
TAXON	Surber 1	Surber 2	Surber 3	Kick
Planaridae (Flatworms) (T)		4		
Crayfish (F)				2
salamander larvae* (U)	1		1	
Total Individuals	60	272	110	184
Taxa	13	7	7	12

* = Not included in abundance or taxa calculations. For observation only.

( ) Classification of Pollution Indicator Organisms
(S) = Sensitive (F) = Facultative (T) = Tolerant (U) = Unclassified

TABLE 6. Abundances of benthic macroinvertebrates collected per sample from the Midstream Honey Branch Station, 08 October 1999.

TAXON	SAMPLE Surber 1	Surber 2	Surber 3	Kick
Insecta				
Ephemeroptera (Mayflies)				
Ameletidae				
Ameletus (F)		8		
Plecoptera (Stoneflies)				
Chloroperlidae (S)	4			
Leuctridae				
Leuctra (F)		56		
Perlodidae (F)	2		10	
Trichoptera (Caddisflies)				
Hydropsychidae (F)	4	20		2
Limnephilidae (F)		4		
Philopotamidae (S)		16		
Polycentropodidae (F)	2	2		
Diptera (True Flies)				
Ceratopogonidae (T)			4	4
Chaoboridae (T)				2
Chironomidae (T)	48	32	56	12
Simuliidae (F)		4		
Stratiomyidae (T)			2	
Tipulidae				
Dicranota (T)	2			
Tipula (T)	2			
Coleoptera (Beetles)				
Elmidae (S)	38	24	6	6
Saldidae (S)	2			
Megaloptera (Hellgrammites)				
Corydalidae				
Corydalus (S)	2			
Collembola (Springtails) (F)			2	
Oligochaeta (Aquatic Worms) (T)	20	16	76	44
Planaridae (Flatworms) (T)	4	4		

Crayfish (F)	2	2	2	6

TABLE 6. Continued.

	SAMPLE			
	Surber 1	Surber 2	Surber 3	Kick
Total Individuals	132	192	158	76
Taxa	13	12	8	7

( ) Classification of Pollution Indicator Organisms
(S) = Sensitive (F) = Facultative (T) = Tolerant (U) = Unclassified

TABLE 7. Abundances of benthic macroinvertebrates collected per sample from the Downstream Honey Branch Station, Mouth of Honey Branch, 08 October 1999.

TAXON	SAMPLE Surber 1	Surber 2	Surber 3	Kick
Insecta				
Ephemeroptera (Mayflies)				
Ameletidae				
Ameletus (F)	4	4	4	
Ephemerellidae				
Ephemerella (F)		2		
Heptageniidae				
Stenonema (S)		1		
Plecoptera (Stoneflies)				
Capniidae (S)		2		
Chloroperlidae (S)	6			
Leuctridae				
Leuctra (F)				4
Trichoptera (Caddisflies)				
Hydropsychidae (F)	6	14	6	
Philopotamidae (S)	6	2	8	
Polycentropodidae (F)			2	
Diptera (True Flies)				
Chironomidae (T)	34	14	14	24
Tipulidae				
Tipula (T)				4
Coleoptera (Beetles)				
Elmidae (S)	4	2	2	
Odonata (Dragonflies)				
Gomphidae (T)	4	1		8
Hagenius (T)				16
Lanthus (T)				20
Collembola (Springtails) (F)			2	
Oligochaeta (Aquatic Worms) (T)	12	9	20	28
Planaridae (Flatworms) (T)			2	
Crayfish (F)		1	2	12

TABLE 7. Continued.

	SAMPLE			
	Surber 1	Surber 2	Surber 3	Kick
Total Individuals	76	52	62	116
Taxa	8	11	10	8

( ) Classification of Pollution Indicator Organisms
(S) = Sensitive (F) = Facultative (T) = Tolerant (U) = Unclassified

TABLE 8. Abundances of benthic macroinvertebrates collected per sample from the Upstream Twelvepole Creek Station, Above confluence with Honey Branch, 08 October 1999.

TAXON	SAMPLE Surber 1	Surber 2	Surber 3	Kick
Insecta				
Ephemeroptera (Mayflies)				
Baetidae				
Baetis (F)	16	12		8
Baetiscidae				
Baetisca (S)	24	20	16	8
Caenidae				
Caenis (S)	12	28	24	12
Ephemerellidae				
Ephemerella (F)	12			
Heptageniidae				
Stenonema (S)	68	124	32	20
Oligoneuriidae				
Isonychia (F)	16	56	32	
Plecoptera (Stoneflies)				
Leuctridae				
Leuctra (F)	8	16	8	4
Taeniopterygidae (F)		16		
Trichoptera (Caddisflies)				
Hydropsychidae (F)	12	20	52	4
Rhyacophilidae (F)	4			
Diptera (True Flies)				
Ceratopogonidae (T)			20	8
Chironomidae (T)	120	128	192	56
Simuliidae (F)	4	16		
Tipulidae				
Hexatoma (T)				4
Coleoptera (Beetles)				
Elmidae (S)	60	96	80	48
Psephenidae (S)	4			
Oligochaeta (Aquatic Worms) (T)	40	120	56	60
Crayfish (F)				4

TABLE 8. Continued.

	SAMPLE			
	Surber 1	Surber 2	Surber 3	Kick
clam* (U)	4	4	8	
snail* (U)		4		
Johnny darter* (U)		1		
Total Individuals	400	652	512	236
Taxa	14	12	10	12

* = Not included in abundance or taxa calculations. For observation only.

( ) Classification of Pollution Indicator Organisms
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TABLE 9. Abundances of benthic macroinvertebrates collected per sample from the Downstream Twelvepole Creek Station, Below confluence with Honey Branch, 08 October 1999.

	SAMPLE			
TAXON	Surber 1	Surber 2	Surber 3	Kick
Insecta				
Ephemeroptera (Mayflies)				
Baetiscidae				
Baetisca (S)	64	26	20	16
Caenidae				
Caenis (S)	12	4	6	8
Heptageniidae				
Stenonema (S)	28	14	32	56
Plecoptera (Stoneflies)				
Capniidae (S)	4	4		
Trichoptera (Caddisflies)				
Hydropsychidae (F)	8		24	
Diptera (True Flies)				
Ceratopogonidae (T)	20		4	
Chironomidae (T)	404	92	132	36
Tipulidae				
Tipula (T)			2	
Coleoptera (Beetles)				
Elmidae (S)	16	24	20	42
Odonata (Dragonflies)				
Coenagrionidae (T)				2
Cordulegastridae				
Cordulegaster (T)			2	3
Oligochaeta (Aquatic Worms) (T)	52	20	24	8
Planaridae (Flatworms) (T)	4			
Crayfish (F)		4	2	5
clam* (U)	4		8	4
Total Individuals	612	188	268	176
Taxa	10	8	11	9

* = Not included in abundance or taxa calculations. For observation only.

( ) Classification of Pollution Indicator Organisms

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TABLE 10. Abundances of benthic macroinvertebrates collected per sample from Middle Honey Branch Pond (Pond Number 2), 08 October 1999.

TAXON	SAMPLE Ponar 1	Ponar 2	Ponar 3
Insecta			
Ephemeroptera (Mayflies)			
Baetidae			
Baetis (F)	96	16	16
Caenidae			
Caenis (F)			64
Ephemeridae			
Hexagenia (S)	32		
Diptera (True Flies)			
Ceratopogonidae (T)	320	160	144
Chironomidae (T)	896	240	384
Tipulidae			
Tipula (T)	32		
Odonata (Dragonflies)			
Coenagrionidae (T)			16
Corduliidae			
Cordulia (T)			16
Oligochaeta (Aquatic Worms) (T)	128	112	48
clams* (U)			16
Total Individuals	1504	528	688
Taxa	6	4	7

* = Not included in abundance or taxa calculations. For observation only.

( ) Classification of Pollution Indicator Organisms
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TABLE 11. Abundances of benthic macroinvertebrates collected per sample from Lower Honey Branch Pond (Pond Number 1), 08 October 1999.

	SAMPLE		
TAXON	Ponar 1	Ponar 2	Ponar 3
Insecta			
Ephemeroptera (Mayflies)			
Caenidae			
Caenis (F)	64		64
Diptera (True Flies)			
Ceratopogonidae (T)	96	256	32
Chironomidae (T)	192	192	304
Odonata (Dragonflies)			
Coenagrionidae (T)	16		
Corduliidae			
Cordulia (T)	16		
Collembola (Springtails) (F)	48		
Oligochaeta (Aquatic Worms) (T)	96		
Crayfish (F)	16		
clams* (U)	80	64	64
Total Individuals	544	448	400
Taxa	8	2	3

* = Not included in abundance or taxa calculations. For observation only.

( ) Classification of Pollution Indicator Organisms
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TABLE 12. Abundances of benthic macroinvertebrates collected per sample from Honey Branch Sediment Ditch, 08 October 1999.

TAXON	SAMPLE Ponar 1	Ponar 2	Ponar 3
Insecta			
Ephemeroptera (Mayflies)			
Baetidae			
Baetis (F)	112	64	96
Diptera (True Flies)			
Ceratopogonidae (T)	288	320	192
Chironomidae (T)	208	320	288
Coleoptera (Beetles)			
Dytiscidae (T)	16		
Haliplidae			
Peltodytes (S)			32
Odonata (Dragonflies)			
Coenagrionidae (T)	16	32	
Collembola (Springtails) (F)	16		
Oligochaeta (Aquatic Worms) (T)		64	128
Total Individuals	656	800	736
Taxa	6	5	5

( ) Classification of Pollution Indicator Organisms
(S) = Sensitive (F) = Facultative (T) = Tolerant (U) = Unclassified

APPENDIX C

Photograph 1. Upstream Honey Branch (Toe of Valley Fill) Station.

Photograph 2. Upstream Honey Branch (Toe of Valley Fill) Station.

Photograph 3. Middle Honey Branch Station.

Photograph 4. Middle Honey Branch Station.

Photograph 5. Middle Honey Branch Pond (Pond Number 2).

Photograph 6. Lower Honey Branch Pond (Pond Number 1).

Photograph 7. Honey Branch Sediment Ditch.

Photograph 8. Honey Branch Sediment Ditch.

Supporting Information Supplied by Randall Maggard:

Downstream Impacts of Surface Mining And Valley Fill Construction

An Evaluation of the Aquatic Habitats Provided by Sediment Control Ponds and Other Aquatic Enhancement Structures Located on Mine Permitted Areas in Southern West Virginia

Benthic Macroinvertebrate Study of Honey Branch, And It's Control Ponds, and It's Influence on The East Fork of the Twelvepole Creek Conducted 10/08/00

AN EVALUATION OF THE AQUATIC HABITATS PROVIDED BY SEDIMENT CONTROL PONDS AND OTHER AQUATIC ENHANCEMENT STRUCTURES LOCATED ON MINE PERMITTED AREAS IN SOUTHERN WEST VIRGINIA.

Conducted For:

PEN COAL CORPORATION
KIAH CREEK MINE OFFICE
P.O. BOX 191
DUNLOW, WEST VIRGINIA 25511

By:

R.E.I. CONSULTANTS, INCORPORATED
ED J. KIRK, AQUATIC BIOLOGIST
225 INDUSTRIAL PARK ROAD
BEAVER, WEST VIRGINIA 25813
11/23/99

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AN EVALUATION OF THE AQUATIC HABITATS PROVIDED BY SEDIMENT CONTROL PONDS AND OTHER AQUATIC ENHANCEMENT STRUCTURES LOCATED ON MINE PERMITTED AREAS IN SOUTHERN WEST VIRGINIA.

INTRODUCTION

Typically, sediment ditches and diversion ditches are constructed on coal company property for 3 purposes: 1) to divert surface runoff into more desirable locations and away from work areas and roads 2) to combine flows from several sources into fewer, more manageable discharges, and 3) to slow surface runoff, often laden with sediments, to allow for a settling of the sediments to occur prior to flows entering streams. The larger, sediment control ponds are generally constructed on coal company property also for 3 purposes: 1) to slow surface runoff, laden with sediments, in order to allow for settling to occur prior to flows entering streams 2) to provide a flow-control structure which allows the operators to manage downstream stream flows during periods of either very low or very high flows, and 3) to provide a point of chemical/physical treatment in the event the water quality needs to be adjusted prior to entering the lower portions of the stream.

Construction of these sediment ditches, diversion ditches, and sediment control ponds is not something that is performed without giving serious consideration to the natural conditions which exist on the area in question. Design and construction is performed on a case-by-case analysis which includes the natural hydrology, geomorphology, watershed size, and aquatic life inhabiting the stream. In essence, these ponds are nothing short of professionally engineered structures, designed to address the stream flows as well as the surface runoff which can be expected from the watershed size, and are designed to conform to the natural topography of the area.

Although generally these structures are not designed with many aesthetic qualities in mind, the conditions which exist after construction of the ponds and ditches automatically create circumstances necessary for the natural creation of wetlands. The presence of the warmer, slow-moving, sediment-laden water provides the nutrients and sediment sizes necessary for the production of several aquatic emergent and submerged aquatic plants such as cattails, milfoil, rushes, and sedges. The existence of the continuous water overlying the pond's bottom initiates the chain of events necessary for the creation of hydric soils also necessary for aquatic vegetation. In addition, the placement of the designed ponds, usually located directly in the stream channel at the base of a hollow, or on a wide, flat bench where subsurface and surface runoff will support the on-bench pond, are planned so that they are self-sustaining. Water from the stream as well as from surface runoff are adequate to ensure the existence of the pond for decades.

Nevertheless, according to the West Virginia Department of Environmental Protection-Office of Mining and Reclamation, upon completion of mining in the area, the constructed sediment control pond and/or drainage ditches must be removed prior to being released from permitting regulations and receiving back the mining bond. Breaching of the dam is therefore required from the point of view that in order to return the stream back to its original state, the stream channel must be change back to its original shape.

The purpose of this study was to provide an unbiased, professional examination of the sediment control ponds and sediment ditches which currently exist on mine permitted areas in southern West Virginia. Several ponds of various ages would be studied as to their aquatic and wetland status, and usefulness as quality habitats for fauna inhabiting the area.

LOCATION OF STUDY SITES

The overall study area is located in Wayne County, in southwestern West Virginia. Ponds sampled were located on Vance Branch (Rollem Fork Number 3 Surface Mine; On-Bench Pond Number BP3), Rollem Fork (Rollem Fork Number 2 Surface Mine; On-Bench Pond Number 5), and Left Fork of Parker Branch (Pond Number 7). Sediment ditches sampled were located on Vance Branch (Rollem Fork Number 3 Surface Mine; Combination Ditch Number CD3), Rollem Fork (Rollem Fork Number 2 Surface Mine; Sediment Ditch Number SD-3), and Left Fork of Parker Branch (Sediment Ditch Number 6).

METHODS OF INVESTIGATION

At each sampled pond or sediment ditch, measurements for physical water quality were taken. Samples were also collected and returned to the laboratory for chemical analysis. Benthic macroinvertebrate samples were also collected, and the habitat of the stations was evaluated. The individual methodologies are described below.

Physical Water Quality/Water Chemistry

Physical water quality was analyzed on-site at each station. Water temperature, Dissolved Oxygen (DO), pH, and conductivity was measured with a Hydrolab™ Minisonde multi-parameter probe.

Water samples were collected at each of the three pond sites as well as the three sediment ditches, appropriately preserved, and transported to R.E.I. Consultant's laboratory for analysis. All analyses utilized current EPA-approved protocols. Parameters measured at each station were Biological Oxygen Demand (BOD), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), hardness, alkalinity, total sulfates, total acidity, sodium, total aluminum, calcium, total iron, total magnesium, total manganese chlorides, fecal coliform, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc.

Habitat

The habitat at each of the sites was assessed, rated, and scored on a few parameters in three categories using EPA Rapid Bioassessment Protocols for Use in Streams and Rivers (EPA 440/4-89/001). Because these parameters were originally developed for streams and rivers, emphasis was placed on the quantity and types of vegetation present, pond/ditch slopes, surface acreage, depth, substrate composition, location of pond/ditch relative to detrimental impacts, and composition of surrounding area (forested, open field, heavy haul traffic area, etc...).

Benthic Macroinvertebrates

At each site, collections were made via a Ponar grab sampler. The Ponar grab sampler has several features which make it a desirable choice for the collection of aquatic macroinvertebrates in lentic habitats such as ponds, lakes, as well as lotic deepwater habitats such as rivers. Sampler area was 81 $inch^2$ per replicate. Three samples were taken near the shoreline, and in the best available spots (lowest siltation, highest percentage of gravel/pebble substrate, highest vegetation) at each station. Samples were placed in 1-gallon plastic containers, preserved in 35% formalin, and returned to the laboratory for processing. Samples were then picked under Unitron™ microscopes and detrital material was discarded only after a second check to insure that no macroinvertebrates had been missed. All macroinvertebrates were identified to lowest practical taxonomic level and enumerated. Metrics were then calculated for each station.

SPECIFIC SITE LOCATIONS / PHYSICAL DESCRIPTIONS

Vance Branch Pond (Rollem Fork Number 3 Surface Mine; On-Bench Pond Number BP3)

This station was located on Vance Branch, and was constructed in 1999 (Figure 1). The pond is approximately 400 feet in length, and is approximately 125 feet wide. At the existing water level, the pond is approximately 300 feet in length, approximately 60 feet wide, and has an area of approximately 0.67 acres. The elevation of the pond's bottom is 984.4 feet above sea level. The existing water depth was only about a foot, but the pond provides for 4.19 acre/feet of accumulative sediment storage. Due to the pond's early completion, the banks were only about 50% vegetated, and this was with various rye and other grasses for erosion control. Aquatic vegetation was minimal except for a small quantity of smartweed (Photographs 1 - 2). The banks were very steep along the hillsides, and were noticeably unstable due to their steepness, lack of vegetation, and composition. Alluvial fans were present from erosion. Adequate soils had not yet formed due to the young age of this structure. This pond had noticeably higher levels of solids (Table 1A) probably due to sediments being washed into the pond easier than at older, more established ponds. There was no pond cover present due to the far distance from the surrounding deciduous forest, and the substrate was comprised mostly of sand and silt (Table 4A).

Rollem Fork (Rollem Fork Number 2 Surface Mine; On-Bench Pond Number 5)

This station was located on Rollem Fork, and was constructed in 1997 (Figure 2). The pond is approximately 200 feet in length, and is approximately 150 feet wide. At the existing water level, the pond is approximately 175 feet in length, approximately 130 feet wide, and has an area of approximately 0.30 acres. The elevation of the pond's bottom is 930.0 feet above sea level. The existing water depth is about 20 feet deep due to the steep slopes (2.1:1) of the side, and the pond provides for 2.70 acre/feet of accumulative sediment storage. Even though the pond was completed in 1997, the banks were almost 100% vegetated (Photographs 3 - 4), and this was with various grasses, herbaceous plants such as St. John's wort, and small saplings such as alder. The banks above water level were not too steep, and were noticeably more stable due to their heavier vegetation. No signs of erosion were present. Soils appeared to be more advanced at this structure. There was only a very little pond cover present from the heavy cattails growing around the pond; there was a far distance from the surrounding deciduous forest. The substrate was comprised mostly of sand and gravel (Table 4A).

Left Fork of Parker Branch (Pond Number 7)

This station was located on the Left Fork of Parker Branch, and was constructed in 1991 (Figure 3). The pond is approximately 160 feet in length, and is approximately 240 feet wide. At the existing water level, the pond is approximately 150 feet in length, approximately 225 feet wide, and has an area of approximately 1.0 acres. The elevation of the pond's bottom is 936.0 feet above sea level. The existing water depth was about 10 feet, and the pond provides for 4.98 acre/feet of accumulative sediment storage. Due to the pond being about 8 years old, the banks were 100% vegetated (Photographs 5 - 6), and this was with various grasses, rushes, golden rod, greenbrier, sycamores. Aquatic vegetation was comprised of milfoil (Myriofyllum sp.), pondweed (Potamogeton sp.), and cattails. The banks were not steep along the hillsides, and were stable due to their low-steepness, heavy vegetation, and soil composition. No signs of erosion were present. There was very little pond cover present due to the far distance from the surrounding deciduous forest, but the heavy vegetation provided some cover along the shoreline areas. The substrate was comprised mostly of silt and sand (Table 4A).

<u>Vance Branch (Rollem Fork Number 3 Surface Mine; Combination Ditch Number CD3)</u>

This station was located on Vance Branch, and was constructed in 1999 (Figure 4). The combination ditch is approximately 2,250 feet in length, is approximately 41 feet wide, and has an area of approximately 2.12 acres. The elevation of the ditch's bottom is about 1000 feet above sea level. The existing water depth was only about a foot, but the combination ditch provides for 4.28 acre/feet of accumulative sediment storage. Even though the ditch was constructed in 1999, the banks were moderately vegetated, and this was with various rye and clover grasses for erosion control. Aquatic vegetation was minimal except for a small quantity of cattails (Photographs 7 - 8). The banks were not too steep along the hillsides, and were noticeably stable due to their low gradient and vegetation. Soils had not yet established due to the young age of this structure. This sediment ditch had noticeably higher levels of suspended solids (Table 1B) probably due to sediments being washed into the structure easier than at older, more established ones. There was no canopy cover present due to the far distance from the surrounding deciduous forest, and the substrate was comprised mostly of silt and clay (Table 4B).

<u>Rollem Fork (Rollem Fork Number 2 Surface Mine; Sediment Ditch Number SD-3)</u>

This station was located on Rollem Fork, and was constructed in 1997 (Figure 5). The sediment ditch is approximately 900 feet in length, is approximately 40 feet wide, and has an area of approximately 0.83 acres. The elevation of the ditch's bottom is about 950 feet above sea level. The existing water depth was only about a few inches, but the sediment ditch provides for 1.67 acre/feet of accumulative sediment storage. Even though the ditch was constructed in 1997, the banks were 100% vegetated, and this was with various rye and clover grasses, and sedges. Aquatic vegetation was mostly the large abundance of cattails (Photographs 9 - 10). The banks were not too steep along the hillsides, and were noticeably stable due to their low gradient and vegetation. Soils had established and were noted to be gleyed at about 1.5" within the area of the wetland. There was no canopy cover present due to the far distance from the surrounding deciduous forest, and the substrate was comprised mostly of vegetated silt (Table 4B).

<u>Left Fork of Parker Branch (Sediment Ditch Number 6)</u>

This station was located on the Left Fork of Parker Branch, and was constructed in 1994 (Figure 6). The sediment ditch is approximately 600 feet in length, is approximately 40 feet wide, and has an area of approximately 0.55 acres. The elevation of the ditch's bottom is about 950 feet above sea level. The existing water depth was about 5 feet, and this sediment ditch provides for over 2.5 acre/feet of accumulative sediment storage. The banks were well vegetated, and this was with various rye and clover grasses, sedges, and goldenrod. Aquatic vegetation consisted of cattails, pondweeds (Potamogeton sp.), and water milfoil (Myriophyllum sp.) (Photographs 11 - 12). There was a heavy algae growth which was presumed to be a result of the higher pH level of this structure (Table 1B). The banks were not too steep along the hillsides, and were noticeably stable due to their low gradient and heavy vegetation. Soils were well established due to the older age of this structure. There was no canopy cover present due to the far distance from the surrounding deciduous forest. The substrate was comprised mostly of clay and silt (Table 4B).

PHYSICAL AND CHEMICAL WATER QUALITY ANALYSIS

Physical and chemical water quality was analyzed at each of the pond and sediment ditch sites sampled on Vance Branch, Rollem Fork, and the Left Fork of Parker Branch. The physical and chemical water quality results are presented in Tables 1A and 1B. Many of the ponds had large differences between like parameters. For instance, the pH on Vance Branch's pond was low with a pH of 5.04, whereas the pH for the pond on the Left Fork of Parker Branch was high with a pH of 8.77. The same observation was true with regards to the sediment ditches. For instance, the pH on Rollem Fork's sediment ditch was low with a pH of 5.32, whereas the pH for the sediment ditch on the Left Fork of Parker Branch was high with a pH of 9.39. Most of the chemical values such as dissolved solids, hardness, sulfates, alkalinity, and most metals were considered fairly high. Although several of these values were considered limiting to the benthic macroinvertebrate communities inhabiting them, it should be remembered that one of the primary purposes of the ponds and sediment ditches is for reducing the high levels of solids and metals by settling them out prior to reaching the downstream portions of the receiving streams.

HABITAT ASSESSMENT

Several habitat measurements were determined (Tables 4A and 4B) at each of the sites sampled. The individual parameters are described below.

Pond/Ditch Surface Acreage - Actual size of the structure in acres. Smaller, shallower ponds and ditches, may not last as long or have as much sediment holding potential, but they will have a larger wetland value as there is less open water and more wetland vegetated area.

Length x Width - Longer, narrower ponds and sediment ditches will eventually have better wetland values for filtering incoming waters and provide more useable habitat for aquatic insects than wider, deeper ponds and sediment ditches.

Accumulative Sediment Storage Potential - Amount of sediment the structure can potentially hold. Larger, deeper ponds and sediment ditches can obviously hold more sediments, but may not have as desirable "wetland" potential.

Bottom Substrate Type - The availability of habitat for support of aquatic organisms. A variety of substrate materials and habitat types is desirable. Substrates comprised of more gravel, pebble, and/or organic materials are more desirable than those comprised mostly of silt and clay.

Bank Stability - Bank stability is rated by observing existing or potential detachment of soil from the upper and lower banks and its potential movement into the structure. Ponds and ditches with poor banks will often have poor instream habitat.

Bank Vegetative Stability - Bank soil is generally held in place by plant root systems. An estimate of the density of bank vegetation covering the bank provides an indication of bank stability and potential instream sedimentation.

Vegetation Type - Describes the vegetation type present. Newer structure will likely have only grasses planted along banks. Older structures can have grasses, several herbaceous species, as well as shrubs and tree saplings. Wetland vegetation on newer structures may not be present, but can consist of several types of algae, submerged and emergent aquatic species at older, more established structure.

Pond/Ditch Cover - Cover vegetation is evaluated in terms of provision of shading and escape cover for fish. A rating is obtained by visually determining the dominant vegetation type covering the exposed pond bottom, bank, and top of bank. Riparian vegetation dominated by shrubs and trees provides the CPOM source in allochthonous systems.

HABITAT RESULTS

Vance Branch (Rollem Fork Number 3 Surface Mine; On-Bench Pond Number BP3)

This on-bench pond had a surface area of 0.67 acres, was 400 feet long by 125 feet wide, and had an accumulative sediment storage potential of 4.19 acre/feet (Table 4A). Due to the recent completion of this structure (1999), banks were only about 50% vegetated, and only with erosional control grasses. The substrate was sandy and silty. Because this structure has tremendous storage potential, it should serve well as a sediment control pond, but banks are steep and unstable, and need to become more established. This structure has fairly good wetland potential as it becomes more established, but only around the edges of the pond, as it will likely have open water in the center for quite some time.

Rollem Fork (Rollem Fork Number 2 Surface Mine; On-Bench Pond Number 5)

This on-bench pond had a surface area of 0.30 acres, was 200 feet long by 150 feet wide, and had an accumulative sediment storage potential of 2.70 acre/feet (Table 4A). Even though it was fairly recently completed (1997), banks were almost 100% vegetated, and with grasses and other herbaceous plants and shrubs. The substrate was sandy and gravely. This structure has good storage potential, and it should serve well as a sediment control pond. Because banks are not steep and stable, this structure will most likely remain an open water pond for quite some time. This structure has good wetland potential along the edge as it becomes more established.

Left Fork of Parker Branch (Pond Number 7)

This pond had a surface area of 1.0 acres, was 160 feet long by 240 feet wide, and had an accumulative sediment storage potential of 4.98 acre/feet (Table 4A). Because it was completed a few years ago in 1994, banks were 100% vegetated, and with grasses and other herbaceous plants, shrubs, and saplings. The substrate was silty. This structure has tremendous storage potential, and it should serve well as a sediment control pond. Because banks are not steep and stable, this structure will most likely remain an open water pond for quite some time. This structure has good wetland potential along the edges, and due to its larger size, may serve very well for waterfowl, fish, and amphibians.

Vance Branch (Rollem Fork Number 3 Surface Mine; Combination Ditch Number CD3)

This combination ditch had a surface area of 2.12 acres, was 2250 feet long by 41 feet wide, and had an accumulative sediment storage potential of 4.28 acre/feet (Table 4B). Although it had a recent completion date (1999), banks were moderately vegetated, but only with erosional control grasses. The substrate was silty, clay. Because this structure has tremendous storage potential, it should serve well as a combination ditch. This structure has fairly good wetland potential as it becomes more established, especially due to its longer, narrower size. Because of its size, it should do very well as a water filtration structure.

Rollem Fork (Rollem Fork Number 2 Surface Mine; Sediment Ditch Number SD-3)

This sediment ditch had a surface area of 0.83 acres, was 900 feet long by 40 feet wide, and had an accumulative sediment storage potential of 1.67 acre/feet (Table 4B). Although it also had a recent completion date (1997), banks were well vegetated, but only with grasses, herbaceous plants, and a few shrubs. The substrate was vegetated silt. Although this structure has a low sediment storage potential, it has a tremendous wetland potential, as it is shallow and long. Because of its length and depth, it should do very well as a water filtration structure.

Left Fork of Parker Branch (Sediment Ditch Number 6)

This sediment ditch had a surface area of 0.55 acres, was 600 feet long by 40 feet wide, and had an accumulative sediment storage potential of at least 2.5 acre/feet (Table 4B). Because of its older completion date (1994), banks were very well vegetated, but only with grasses, herbaceous plants, and a few shrubs. The substrate was vegetated silty clay. This structure has a higher sediment storage potential, and should perform well as a sediment control device. It also has good wetland and open water habitat potential.

DESCRIPTION OF BENTHIC MACROINVERTEBRATE METRICS

Several benthic macroinvertebrate measurements were calculated (Tables 3A and 3B) for each of the pond and sediment ditch sites sampled. The individual metrics are described below.

Metric 1. Taxa Richness - Reflects the health of the community through a measurement of the variety of taxa present. Generally increases with increasing water quality, habitat diversity, and habitat suitability. However, the majority should be distributed in the pollution sensitive groups, a lesser amount in the facultative groups, and the least amount in the tolerant groups. Polluted streams shift to tolerant dominated communities.

Metric 2. Modified Hilsenhoff Biotic Index - This index was developed by Hilsenhoff (1987) to summarize overall pollution tolerance of the benthic arthropod community with a single value. Calculated by summarizing the number in a given taxa multiplied by its tolerance value, then divided by the total number of organisms in the sample.

Metric 3. Ratio of Scraper and Filtering Collector Functional Feeding Groups - This ratio reflects the riffle/run community foodbase and provides insight into the nature of potential disturbance factors. The relative abundance of scrapers and filtering collectors indicate the periphyton community composition, availability of suspended Fine Particulate Organic Material (FPOM) and availability of attachment sites for filtering. Filtering collectors are sensitive to toxicants bound to fine particles and should be the first group to decrease when exposed to steady sources of bound toxicants.

Metric 4. Ratio of Ephemeroptera, Plecoptera, Trichoptera (EPT) and Chironomidae Abundances - This metric uses relative abundance of these indicator groups as a measure of community balance. Good biotic condition is reflected in communities having a fairly even distribution among all four major groups and with substantial representation in the sensitive groups Ephemeroptera, Plecoptera, and Trichoptera. Skewed populations with large amounts of Chironomidae in relation to the EPT indicates environmental stress.

Metric 5. Percent Contribution of Dominant Family - This is also a measure of community balance. A community dominated by relatively few species would indicate environmental stress. A healthy community is dominated by pollution sensitive representation in the Ephemeroptera, Plecoptera, and Trichoptera groups.

Metric 6. EPT Index - This index is the total number of distinct taxa within the Orders: Ephemeroptera, Plecoptera, and Trichoptera. The EPT Index generally increases with increasing water quality. The EPT index summarizes the taxa richness within the pollution sensitive insect orders.

Metric 7. Ratio of Shredder Functional Feeding Group and Total Number of Individuals Collected - Allows evaluation of potential impairment as indicated by the shredder community. Shredders are good indicators of riparian zone impacts.

Metric 8. Simpson's Diversity Index - This index ranges from 0 (low diversity) to almost 1 (high diversity). A healthy benthic macroinvertebrate community should have a higher Simpson's Diversity Index.

Metric 9. Shannon-Wiener Diversity Index - Measures the amount of order in the community by using the number of species and the number of individuals in each species. The value increases with the number of species in the community. A healthy benthic macroinvertebrate community should have a higher Shannon-Wiener Diversity Index.

Metric 10. Shannon-Wiener Evenness - Measures the evenness, or equitability of the community by scaling one of the heterogeneity measures relative to its maximal value when each species in the sample is represented by the same number of individuals. Ranges from 0 (low equitability) to 1 (high equitability).

BENTHIC MACROINVERTEBRATE RESULTS

Vance Branch (Rollem Fork Number 3 Surface Mine; On-Bench Pond Number BP3)

A total of 1,144 individuals comprising 8 taxa were collected (Tables 2A and 5). No pollution sensitive (intolerant) taxa were present in this pond. Only one facultative (intermediate tolerance) taxa was present (the springtail Collembola) which comprised 0.3% of the sample. Seven tolerant taxa were present comprising 99.7% of the abundance at this site. The tolerant Dipteran, Chironomidae accounted for 88.5% of the total abundance, and was the most abundant taxa present at this pond on Vance Branch. No EPT groups (mayflies, stoneflies, and caddisflies) were present. No scrapers or collector/filterers were present (Table 3A). The Simpson's and Shannon-Wiener Diversity indices reflected a poorly diversified community; the Shannon-Wiener Evenness value of 0.25 indicated that abundances were poorly distributed among the taxa, or homogeneous. The Modified Hilsenhoff Biotic Index (HBI) and the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) indicated a heavily pollution tolerant macroinvertebrate community with a relatively poor periphyton community composition.

Rollem Fork (Rollem Fork Number 2 Surface Mine; On-Bench Pond Number 5)

A total of 2,800 individuals comprising 12 taxa were collected (Tables 2A and 6). No pollution sensitive (intolerant) taxa were present in this on-bench pond. Five facultative (intermediate tolerance) taxa were present comprising 22.7% of the sample. The facultative mayfly Caenis (Family: Caenidae) accounted for 16.4% of the site's abundance, and was a significant component to the site's community. Seven tolerant taxa were present comprising 77.3% of the abundance at this site. The tolerant Dipteran, the midge, Chironomidae accounted for 69.1% of the total abundance, and was the most abundant taxa at this sediment pond on Rollem Fork. Four EPT groups (Table 3A) were present which contributed to the EPT:Chironomidae Index in being fairly desirable. No scrapers or collector/filterers were present. A moderate variety of mayflies and caddisflies were collected at this station. The Simpson's and Shannon-Wiener Diversity indices reflected a community moderately-low in diversity, and the Shannon-Wiener Evenness indicated that abundances were only moderately distributed among the taxa. The Modified Hilsenhoff Biotic Index (HBI) and the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) indicated a pollution tolerant/facultative, but fairly healthy benthic macroinvertebrate community.

Left Fork of Parker Branch (Pond Number 7)

A total of 4,936 individuals comprising 14 taxa were collected (Tables 2A and 7). No pollution sensitive (intolerant) taxa were present in this pond. Three facultative (intermediate tolerance) taxa were present comprising 20.4% of the sample. The facultative mayfly Caenis (Family: Caenidae) accounted for 13.6% of the site's abundance, and was a significant component to the site's community. Eleven tolerant taxa were present comprising 79.6% of the abundance at this site. The tolerant aquatic worm, Oligochaeta, accounted for 38.2% of the total abundance, and was the most abundant taxa at this sediment pond on the Left Fork of

Parker Branch. Three EPT groups (Table 3A) were present which contributed to the EPT:Chironomidae Index in being very desirable. Again, no scrapers or collector/filterers were present, however, a moderate variety of mayflies and caddisflies were collected at this station. The Simpson's and Shannon-Wiener Diversity indices reflected a community moderately-high in diversity, and the Shannon-Wiener Evenness indicated that abundances were well distributed among the taxa. The Modified Hilsenhoff Biotic Index (HBI) and the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) indicated a pollution tolerant/facultative, but fairly healthy benthic macroinvertebrate community.

Vance Branch (Rollem Fork Number 3 Surface Mine; Combination Ditch Number CD3)

A total of 464 individuals comprising 8 taxa were collected (Tables 2B and 8). No pollution sensitive (intolerant) taxa were present in this combination ditch. Two facultative (intermediate tolerance) taxa were present which comprised 1.7% of the sample. The facultative mayfly Baetis (Family: Baetidae) and the springtail, Collembola, each accounted for 0.85% of the site's abundance. Six tolerant taxa were present comprising 98.3% of the abundance at this site. The tolerant Dipteran, Chironomidae accounted for 73.3% of the total abundance, and was the most abundant taxa present at this combination ditch on Vance Branch. Only one EPT group (mayflies, stoneflies, and caddisflies) was present. No scrapers or collector/filterers were present (Table 3B). The Simpson's and Shannon-Wiener Diversity indices reflected a poorly diversified community; the Shannon-Wiener Evenness value of 0.46 indicated that abundances were also relatively poorly distributed among the taxa, or homogeneous. The Modified Hilsenhoff Biotic Index (HBI) and the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) indicated a very heavily pollution tolerant macroinvertebrate community with a relatively poor periphyton community composition.

Rollem Fork (Rollem Fork Number 2 Surface Mine; Sediment Ditch Number SD-3)

A total of 2,576 individuals comprising 4 taxa were collected (Tables 2B and 9). No pollution sensitive (intolerant) taxa were present in this sediment ditch. No facultative (intermediate tolerance) taxa were present either. Four tolerant taxa were present comprising 100.0% of the abundance at this site. The tolerant aquatic worm, Oligochaeta, accounted for 42.2% of the total abundance, and was the most abundant taxa at this sediment ditch on Rollem Fork. No EPT groups (mayflies, stoneflies, or caddisflies) (Table 3B) were present, and no scrapers or collector/filterers were present. The Simpson's and Shannon-Wiener Diversity indices reflected a community moderately-low in diversity, and the Shannon-Wiener Evenness indicated that abundances were only moderately distributed among the taxa. The Modified Hilsenhoff Biotic Index (HBI) and the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) indicated a very pollution tolerant benthic macroinvertebrate community.

Left Fork of Parker Branch (Sediment Ditch Number 6)

A total of 1,120 individuals comprising 12 taxa were collected (Tables 2B and 10). No pollution sensitive (intolerant) taxa were present in this sediment ditch. Four facultative (intermediate tolerance) taxa were present comprising 11.4% of the sample. The facultative mayfly Caenis (Family: Caenidae) accounted for 9.3% of the site's abundance, and was a significant component to the site's community. Eight tolerant taxa were present comprising 88.6% of the abundance at this site. The tolerant midge, Chironomidae, accounted for 42.9% of the total abundance, and was the most abundant taxa at this sediment ditch on the Left Fork of Parker Branch. Three EPT groups (Table 3B) were present which contributed to the EPT:Chironomidae Index in being fairly desirable. Again, no scrapers or collector/filterers were present, however, a moderate variety of mayflies and caddisflies were collected at this station. The Simpson's and Shannon-Wiener Diversity indices reflected a community moderately-high in diversity, and the Shannon-Wiener Evenness indicated that abundances were moderately-well distributed among the taxa. The Modified Hilsenhoff Biotic Index (HBI) and the relative percentages of the three tolerance groups (sensitive, facultative, and tolerant) indicated a pollution tolerant/facultative, but fairly healthy benthic macroinvertebrate community.

DISCUSSION

When comparing total abundances and taxa (Table 2A) between the three sediment control ponds sampled on October 08, 1999, it is obvious that large differences exist. The pond on Vance Branch (Rollem Fork Number 3 Surface Mine; On-Bench Pond Number BP3) contained relatively low abundances and low taxa diversity compared to the other ponds sampled, but this pond was only recently completed and therefore had not yet established an aquatic community (both vegetation and insects). Furthermore, this pond had a limiting pH level as well as limiting acidity, aluminum, and iron levels (Table 1A). The pond on Rollem Fork (Rollem Fork Number 2 Surface Mine; On-Bench Pond Number 5) had large total abundances of aquatic insects as well as a desirable number of taxa present even though this was also a relatively new pond (completion date 1997). This was most likely due to the more desirable pH level, and lower acidity, aluminum, and iron levels. The pond on the Left Fork of Parker Branch (Pond Number 7) contained the largest total abundance of aquatic insects as well as the largest number of taxa collected. This was largely due to the older age of the structure (completed in 1991), and due to the lower levels of most metals, even though pH was considered somewhat limiting.

When comparing total abundances and taxa (Table 2B) between the three sediment control ditches sampled on October 08, 1999, it is also obvious that large differences exist. The sediment ditch on Vance Branch (Rollem Fork Number 3 Surface Mine; Combination Ditch Number CD3) contained low abundances, but moderate taxa diversity. Of the water chemistry parameters tested, only sulfates appeared to be high, thus the recent completion date of this combination ditch and hence the lack of adequate vegetation growth may have been limiting factors. The sediment ditch sampled on Rollem Fork (Rollem Fork Number 2 Surface Mine; Sediment Ditch Number SD-3) contained the highest total abundances, but lowest taxa diversity of all the sediment ditches sampled. The relatively recent completion date (1997) and the low pH level (Table 1B) were possible limiting factors. The sediment ditch sampled on the Left Fork of Parker Branch (Sediment Ditch Number 6) contained a moderate abundance of aquatic insects, and contained the largest number of taxa. This was somewhat a surprise since the pH level (9.39) was considered limiting.

In general, most of the ponds and sediment control ditches sampled were well represented by the groups of aquatic insects which are normally present in these lentic type habitats. The functional feeding groups scrapers and collector/filterers were never present, but this was not surprising since scrapers need silt-free environments for them to feed on the periphyton that attaches to rock substrates, and since the collector/filterers require faster-moving water in order to feed on the small particles of food which collected on constructed silken nets or on hairs on their bodies. The shredder functional feeding group (those that shred and consume leaves and other detrital materials) was also not well represented, but this group is also considered to be sensitive to disturbances and pollution. Generally, the sites were comprised mostly of tolerant organisms such as midges, dragonflies, and aquatic worms. As stated previously, this was to be expected, and was representative of aquatic insects which thrive in pond-type habitats.

Primarily, there are two reasons for the differences in aquatic insect abundances and taxa diversity between the different sediment ponds and sediment ditches: the age of the structure and water chemistry. The age of the structure is an important factor for several reasons. First, the age determines the overall composition of sediments entering the structure. Newly constructed ponds and sediment ditches are far more likely to receive very large inputs of fill materials and materials employed during the many cutting, grading, and logging activities that occur during the construction processes. Since banks and surrounding areas are barren until erosional-control grasses can be established, precipitation events can add large inputs into the new structure and cause erosional water marks. Older structures, with their established soils and heavier surrounding vegetation can "soak up" or slow much of the rainfall which would have undoubtably scarred newer structures. Second, older structures usually can have surrounding vegetation in the forms of large herbaceous plants, shrubs, and if old enough, saplings and larger trees. These larger plant forms add the detrital materials (leaves and sticks) which are a major source of food input for the aquatic insects inhabiting the sediment control pond or ditch. Thus, older, more established ponds will generally have more insects which feed directly upon the detrital materials which enter the system. These detrital materials are also a key source of the sediments which are necessary for many of the emergent and submerged aquatic plants which will eventually be desirable in the system. Newer structures must rely on food materials entering directly from the incoming streams or being flushed in from surface runoff. Newer structures with poor or unestablished benthic soils do not have the capability to produce the varieties and abundances of aquatic plants that older, more established ponds and ditches possess. Third, heavy surrounding vegetation as well as the aquatic vegetation is the "key" to a wetland's ability to facilitate water filtration. Older, more established ponds and sediment ditches, with heavy vegetation in and around the structure, are excellent at filtering solids and contaminants from the water. This is important if a goal of the structure was to remove solids and other contaminants by filtration or precipitation prior to them entering waterways farther downstream. Newer structures do not have nearly as much filtration capability as older, more vegetated ones. Fourth, the closer surrounding vegetation of the older structures provides shading to the pond's or sediment ditch's shoreline areas, thus providing hiding places for fish (if present), cooler temperatures, and places for terrestrial insects to thrive. Older structures are generally warmer along shoreline areas, and have less areas for terrestrial insects to concentrate. An important note to remember is that when most aquatic insects emerge from their aquatic stage to become an adult, they generally live near the water, and many utilize the surrounding vegetation as places to emerge, mate, and lay eggs.

As stated earlier, water chemistry is also on of the reasons for the differences in aquatic insect abundances and taxa diversity between the different sediment ponds and sediment ditches. Water chemistry is critical because it is directly responsible for two components: the aquatic insects living in the pond or sediment ditch, and the vegetation living both in and around the structure. In essence, poor water chemistry can limit, or completely exclude, the abundances and number of taxa inhabiting the aquatic resource regardless of the structure's physical habitat. Good water chemistry can provide for at least some aquatic insect communities even in the most silted environments containing hardly any food inputs. However, aquatic insects require plants, both living and dead. They utilize the dead plants (leaves, sticks) as food sources, refuge places, and even home structures. They directly use the plants living in the pond also as food sources, refuge places, and home structures, but also use them indirectly as water purifiers and as a major source of their oxygen. Normally, ponds and sediment ditches with a very good establishment of aquatic, semi-aquatic, and terrestrial vegetation will have desirable aquatic insect populations and better water quality compared to a similar, or newer, system without established vegetation. It is critical to remember that none of the aquatic, semi-aquatic, or larger terrestrial vegetation was seeded by the mining company. Waterfowl traveling from pond to pond, ingesting the seeds from the wetland vegetation, then depositing the passed seeds at different pond locations has eventually established the vegetation present at each location. Only the perennial rye, orchard grasses, and clover are used by the mining company for erosional control on newly constructed, or disturbed sites.

These sediment ponds and sediment ditches have added an additional facet to the available habitat that is currently present on mine permitted lands. Regarding the sediment ditches and channels, the Pen Coal Corporation has currently constructed over 6 miles of additional sediment channels. Most of these constructed channels were not stream channels prior to their construction. This relates to over 6 miles of additional aquatic habitat (both stream channel and wetland) which was previously non-existent prior to their construction. With regards to the "on-bench" ponds, it is very important to remember that no aquatic habitat was present in the immediate area prior to their construction. Because they were not constructed from damming an existing mountain stream, but rather from digging a hole and building up the area around the pit, no stream channels were sacrificed. They are supported entirely from surface runoff and subsurface seepage, and not from intermittent or perennial streams. Without on-bench pond and the sediment ponds located at the bottom of hollows, there would be no "natural" ponds available in the area. As an example, on land owned or leased by the Pen Coal Corporation, there are currently over 20 on-bench ponds. With each of these averaging about ½ acre in size, Pen Coal has provided over 10 acres of pond and wetland habitat with just their on-bench ponds. This does not include ponds located at the bottoms of hollows, where some stream length was sacrificed for pond/wetland acreage. This 10 acres is entirely additional pond and subsequent wetland habitat that was not available prior to their construction. These lower ponds, on-bench ponds, and sediment ditches are readily used by aquatic insects, waterfowl, amphibians, reptiles, turkeys and other wildlife creatures. An advantage to the animals which utilize the on-bench ponds, is that they do not have to travel to the bottoms of the hollows for water; they now have water sources closer to the ridgetops with the on-bench ponds. It should also be pointed out that this study was conducted during a serious drought year, and that many small streams were dry, but each of the on-bench ponds and lower elevation ponds still contained a more than adequate supply of water.

It seems ill-conceived that all sediment ditches and sediment control ponds have to be removed in order for coal companies to have fulfilled their obligation to "return the stream to its original state". Return of a stream to its original condition may never be achieved as dramatic changes to the geomorphology of the area most likely have occurred during active mining practices. Even if surrounding areas become heavily vegetated or even wooded, the fill materials exposed can alter water chemistry for many years after mining has ceased in the area. In addition, destruction of these ponds and sediment ditches along with their established wetland areas seems to be a direct violation of the practices established by the U.S. Environmental Protection Agency as well as the U.S. Army Corps of Engineers of avoiding elimination of any wetland areas.

If constructed properly, these sediment control ponds and sediment ditches can do a splendid job in removing solids and other water contaminants both by filtration and by precipitation prior to reaching downstream areas. They also provide aquatic habitats for countless abundances of aquatic insects, amphibians, reptiles, and potentially even fish. Once mining has ceased in the immediate area, these sedimentation ponds could easily be converted into an aesthetic, attractive, and usable wildlife feature with only a few modifications. For example, trees felled into the pond would add both food and habitat for many species of aquatic insects. Additional structures could be placed in the pond to provide hiding habitat for lentic fish species such as sunfish and bass. These structures would also provide a refuge for both fish and insects, act as a breeding ground for many species of insects as well as some fish. Although prohibited from planting permanent, larger-growing vegetation such as trees around structures which are considered temporary, changes in management design could take place these structures were to be considered as a permanent, and additional habitat for the area. Tall grasses, shrubs, and willow saplings, as well as larger trees could then be planted surrounding the pond to provide both a food source from fallen leaves/sticks and shade along shoreline areas. The managed pond could also be easily utilized as a refuge by waterfowl and other lentic-water animals such as amphibians and reptiles. With very little modification, most of the ponds studied for this report could provide an additional facet to the aquatic and semi-aquatic fauna currently found in area.

CONCLUSIONS

Overall, most of the ponds and sediment control ditches sampled were well represented by the groups of aquatic insects which are normally present in these lentic type habitats. The functional feeding groups scrapers and collector/filterers were never present, but this was not surprising since scrapers need silt-free environments for them to feed on the periphyton that attaches to rock substrates, and since the collector/filterers require faster-moving water in order to feed on the small particles of food which collected on constructed silken nets or on hairs on their bodies. The shredder functional feeding group (those that shred and consume leaves and other detrital materials) was also not well represented, but this group is also considered to be sensitive to disturbances and pollution. Generally, the sites were comprised mostly of large abundances and taxa of tolerant organisms such as midges, dragonflies, and aquatic worms. As stated previously, this was to be expected, and was representative of pond-type habitats.

Generally, there are two reasons for the differences in aquatic insect abundances and taxa diversity between the different sediment ponds and sediment ditches: the age of the structure and water chemistry. The age of the structure is an important factor because it determines the overall composition of sediments entering the structure, determines the amount of detrital materials (leaves and sticks) entering the system, determine the type and abundance of aquatic vegetation growing in and around the structure, determine the abundances and types of aquatic insects which can be supported in the system, and determine the filtering potential of the system. Water chemistry is critical because it is directly responsible for two components: the aquatic insects living in the pond or sediment ditch, and the vegetation living both in and around the structure. In essence, poor water chemistry can limit, or completely exclude, the abundances and number of taxa inhabiting the aquatic resource regardless of the structure's physical habitat.

These sediment ponds and sediment ditches have added an additional facet to the available habitat that is currently present on mine permitted lands. Regarding the sediment ditches and channels, the Pen Coal Corporation has currently constructed over 6 miles of additional sediment channels. Most of these constructed channels were not stream channels prior to their construction. With regards to the "on-bench" ponds, it is very important to remember that no aquatic habitat was present in the immediate area prior to their construction. On land owned or leased by the Pen Coal Corporation, there are currently over 20 on-bench ponds. With each of these averaging about ½ acre in size, Pen Coal has provided over 10 acres of pond and wetland habitat with just their on-bench ponds. These lower ponds, on-bench ponds, and sediment ditches are readily used by aquatic insects, waterfowl, amphibians, reptiles, turkeys and other wildlife creatures.

It appears to be an ill-conceived policy that all sediment ditches and sediment control ponds have to be removed in order for coal companies to have fulfilled their obligation to "return the stream to its original state". Return of a stream to its original condition may never be achieved as dramatic changes to the geomorphology of the area have most likely occurred during active mining practices. If surrounding areas become heavily vegetated or even wooded, the fill materials exposed can alter water chemistry for many years after mining has ceased in the area. In addition, destruction of these ponds and sediment ditches along with their established wetland areas seems to be a direct violation of the practices established by the U.S. Environmental Protection Agency as well as the U.S. Army Corps of Engineers of avoiding elimination of any wetland areas.

If constructed properly, these sediment control ponds, sediment ditches, and their subsequent wetlands can do a splendid job in removing solids and other water contaminants both by filtration and by precipitation prior to reaching downstream areas. They also provide aquatic habitats for countless abundances of aquatic insects, amphibians, reptiles, and potentially even fish. Once mining has ceased in the immediate area, these sedimentation ponds could easily be converted into an aesthetic, attractive, and useful habitat feature, and provide an additional facet to the aquatic, semi-aquatic, and terrestrial wildlife currently found in area.

APPENDIX A

APPENDIX B

TABLE 1A. Physical and chemical water-quality variables of sediment control ponds at Pen Coal Corporation, 08 October 1999.

PARAMETER	Vance Branch (1999)	Rollem Fork (1997)	Left Fork Parker (1991)
Temperature (?C)	14.00	19.42	18.96
Dissolved Oxygen (mg/l)	6.73	6.45	9.61
pH (SI units)	5.04	7.82	8.77
Conductivity (? mhos)	43	189	273
BOD (mg/l)	<2	<2	3
TDS (mg/l)	602	188	278
TSS (mg/l)	554	21	1
Fecal Coliform (#/100ml)	>800	70	1
Hardness (mg/l)	26.5	134	212
Alkalinity (mg/l)	2.5	85.4	74.4
Total Acidity (mg/l)	11.2	<1.0	<1.0
Chlorides (mg/l)	<1.0	<1.0	<1.0
Sulfates (mg/l)	22.6	61.3	139
Aluminum (mg/l)	8.29	0.544	0.053
Antimony (mg/l)	<0.001	<0.001	<0.001
Arsenic (mg/l)	0.003	0.003	<0.002
Barium (mg/l)	0.080	0.040	0.040
Beryllium (mg/l)	<0.001	<0.001	<0.001
Cadmium (mg/l)	<0.0003	<0.0003	<0.0003
Calcium (mg/l)	4.28	34.4	41.1
Chromium (mg/l)	0.008	<0.001	<0.001
Copper (mg/l)	0.013	<0.005	<0.005
Iron (mg/l)	9.79	1.05	0.037
Lead (mg/l)	0.010	<0.002	<0.002
Magnesium (mg/l)	3.85	11.8	26.5
Manganese (mg/l)	0.410	0.160	0.030
Mercury (mg/l)	<0.0002	<0.0002	<0.0002
Nickel (mg/l)	<0.030	<0.030	<0.030
Selenium (mg/l)	<0.003	<0.003	<0.003
Silver (mg/l)	<0.004	<0.004	<0.004
Sodium (mg/l)	0.836	1.16	2.09
Thallium (mg/l)	<0.001	<0.001	<0.001

Zinc (mg/l)	0.034	0.019	<0.002

TABLE 1B. Physical and chemical water-quality variables of sediment ditches at Pen Coal Corporation, 08 October 1999.

PARAMETER	Vance Branch (1999)	Rollem Fork (1997)	Left Fork Parker (1991)
Temperature (?C)	14.38	10.05	18.36
Dissolved Oxygen (mg/l)	7.43	5.42	9.46
pH (SI units)	7.03	5.32	9.39
Conductivity (? mhos)	365	281	96
BOD (mg/l)	<2	<2	<2
TDS (mg/l)	302	288	84
TSS (mg/l)	172	16	3
Fecal Coliform (#/100ml)	>270	49	14
Hardness (mg/l)	285	182	71.0
Alkalinity (mg/l)	39.2	5.8	67.1
Total Acidity (mg/l)	<1.0	13.2	<1.0
Chlorides (mg/l)	<1.0	1.3	1.2
Sulfates (mg/l)	243	210	15.8
Aluminum (mg/l)	0.714	0.491	0.109
Antimony (mg/l)	<0.001	<0.001	<0.001
Arsenic (mg/l)	0.002	0.002	<0.002
Barium (mg/l)	0.023	0.048	0.034
Beryllium (mg/l)	<0.001	<0.001	<0.001
Cadmium (mg/l)	<0.0003	<0.0003	<0.0003
Calcium (mg/l)	71.6	43.0	17.7
Chromium (mg/l)	<0.001	<0.001	<0.001
Copper (mg/l)	<0.005	<0.005	<0.005
Iron (mg/l)	0.422	1.28	0.132
Lead (mg/l)	<0.002	<0.002	<0.002
Magnesium (mg/l)	25.8	18.2	6.50
Manganese (mg/l)	1.44	3.94	0.017
Mercury (mg/l)	<0.0002	<0.0002	<0.0002
Nickel (mg/l)	<0.030	0.036	<0.030
Selenium (mg/l)	<0.003	0.003	<0.003
Silver (mg/l)	<0.004	<0.004	<0.004
Sodium (mg/l)	1.12	1.08	0.690

Thallium (mg/l)	<0.001	<0.001	<0.001
Zinc (mg/l)	0.023	0.074	<0.002

TABLE 2A. Total abundances of benthic macroinvertebrates collected via Ponar grab samples taken from sediment control ponds at the Pen Coal Corporation, 08 October 1999.

TAXON	Vance Branch (1999)	Rollem Fork (1997)	Left Fork Parker (1991)
Insecta			
Ephemeroptera (Mayflies)			
Baetidae			
Baetis (F)			272
Caenidae			
Caenis (F)		460	672
Ephemerellidae			
Ephemerella (F)		64	
Trichoptera (Caddisflies)			
Polycentropodidae (F)		32	
Rhyacophilidae (F)		64	64
Diptera (True Flies)			
Ceratopogonidae (T)	76	76	416
Chironomidae (T)	1012	1936	976
Coleoptera (Beetles)			
Amphizoidae (T)			64
Dytiscidae (T)	12		48
Cybister (T)			72
Laccophilus (T)	12		
Haliplidae			
Haliplus (T)			8
Hemiptera (Water Bugs)			
Corixidae (T)	4	20	
Mesoveliidae (T)			136
Odonata (Dragonflies)			
Aeshnidae			
Gynacantha (T)			64
Coenagrionidae (T)	20	72	96
Gomphidae (T)			
Dromogomphus (T)		4	
Libellulidae (T)		40	160

Insecta

TABLE 2A. Continued

TAXON	Vance Branch (1999)	Rollem Fork (1997)	Left Fork Parker (1991)
Collembola (F)	4	16	
Oligochaeta (AquaticWorms) (T)	4	16	1888
smallmouth bass juvenile* (U)		1	
Total Individuals	1,144	2,800	4,936
Total Taxa	8	12	14
Sensitive Ind. (%)	0 (0.0)	0 (0.0)	0 (0.0)
Number of Taxa	0	0	0
Facultative Ind. (%)	4 (0.3)	636 (22.7)	1008 (20.4)
Number of Taxa	1	5	3
Tolerant Ind. (%)	1140 (99.7)	2164 (77.3)	3928 (79.6)
Number of Taxa	7	7	11

* = Not included in abundance or taxa calculations. For observation only.

( ) Classification of Pollution Indicator Organisms
(S) = Sensitive (F) = Facultative (T) = Tolerant (U) = Unclassified

TABLE 2B. Total abundances of benthic macroinvertebrates collected via Ponar grab samples taken from sediment ditches at the Pen Coal Corporation, 08 October 1999.

TAXON	Vance Branch (1999)	Rollem Fork (1997)	Left Fork (1994)
Insecta			
Ephemeroptera (Mayflies)			
Baetidae			
Baetis (F)	4		8
Caenidae			
Caenis (F)			104
Trichoptera (Caddisflies)			
Polycentropodidae (F)			8
Diptera (True Flies)			
Ceratopogonidae (T)	64	448	40
Chironomidae (T)	340	1024	480
Tipulidae			
Tipula (T)			16
Coleoptera (Beetles)			
Amphizoidae (T)	4		
Dytiscidae			
Cybister (T)			8
Laccophilus (T)	8		
Hydrophilidae			
Berosus (T)		16	
Hemiptera (Water Bugs)			
Mesoveliidae (T)			24
Odonata (Dragonflies)			
Coenagrionidae (T)			80
Libellulidae (T)	32		104
Collembola (F)	4		8
Oligochaeta (Aquatic Worms) (T)	8	1088	240
Total Individuals	464	2,576	1,120
Total Taxa	8	4	12

TABLE 2B. Continued

	Vance Branch (1999)	Rollem Fork (1997)	Left Fork (1994)
Sensitive Ind. (%)	0 (0.0)	0 (0.0)	0 (0.0)
Number of Taxa	0	0	0
Facultative Ind. (%)	8 (1.7)	0 (0.0)	128 (11.4)
Number of Taxa	2	0	4
Tolerant Ind. (%)	456 (98.3)	2576 (100.0)	992 (88.6)
Number of Taxa	6	4	8

( ) Classification of Pollution Indicator Organisms
(S) = Sensitive (F) = Facultative (T) = Tolerant (U) = Unclassified

TABLE 3A. Selected benthic macroinvertebrate metrics for sediment control ponds located at the Pen Coal Corporation, 08 October 1999.

METRIC	Vance Branch (1999)	Rollem Fork (1997)	Left Fork Parker (1991)
Taxa Richness	8	12	14
Modified Hilsenhoff Biotic Index	6.05	6.03	6.06
Ratio of Scrapers to Collector/Filterers	0:0	0:0	0:0
Ratio of EPT:Chironomidae	0:1012	620:1936	1008:976
% Contribution of Dominant Family	88.5% Chiro.[1]	69.1% Chiro.[1]	38.2% Olig.[2]
EPT Index	0	4	3
% Shredders to Total	0.3%	0.6%	0.0%
Simpson's Diversity Index	0.21	0.49	0.78
Shannon-Wiener Diversity	0.74	1.63	2.74
Shannon-Wiener Evenness	0.25	0.46	0.72

1 = Diptera: Chironomidae
2 = Oligochaeta

TABLE 3B. Selected benthic macroinvertebrate metrics for sediment ditches located at the Pen Coal Corporation, 08 October 1999.

METRIC	Vance Branch (1999)	Rollem Fork (1997)	Left Fork (1994)
Taxa Richness	8	4	12
Modified Hilsenhoff Biotic Index	6.19	6.00	6.53
Ratio of Scrapers to Collector/Filterers	0:0	0:0	0:0
Ratio of EPT:Chironomidae	4:340	0:1024	120:480
% Contribution of Dominant Family	73.3% Chiro.[1]	42.2% Olig.[2]	42.9% Chiro.[1]
EPT Index	1	0	3
% Shredders to Total	0.9%	0.0%	0.7%
Simpson's Diversity Index	0.44	0.63	0.75
Shannon-Wiener Diversity	1.37	1.54	2.49
Shannon-Wiener Evenness	0.46	0.77	0.69

1 = Diptera: Chironomidae
2 = Oligochaeta

TABLE 4A. Summary of habitat descriptions for the sediment control ponds located at the Pen Coal Corporation, 08 October 1999.

	Vance Branch (1999)	Rollem Fork (1997)	Left Fork Parker (1991)
Pond/Ditch Surface Acreage			
	0.67	0.30	1.0
Length x Width (feet)			
	400 x 125	200 x 150	160 x 240
Accumulative Sediment Storage (Acre/feet)			
	4.19	2.70	4.98
Bottom Substrate Type			
	sand, silt	sandy, gravel	silty
Bank Stability			
	very steep, unstable	stable	stable
Bank Vegetation Stability			
	? 50% vegetated	100% vegetated	100% vegetated
Vegetation Types			
	grasses (terrestrial)	grasses, shrubs, herbaceous plants, filamentous algae	grasses, shrubs, herbaceous plants, filamentous algae, emergent aquatics
Pond/Ditch Cover			
	none	very little	very little

TABLE 4B. Habitat descriptions for the sediment control ditches located at the Pen Coal Corporation, 08 October 1999.

	Vance Branch (1999)	Rollem Fork (1997)	Left Fork (1994)
Pond/Ditch Surface Acreage			
	2.12	0.83	0.55
Length x Width (feet)			
	2,250 x 41	900 x 40	600 x 40
Accumulative Sediment Storage (Acre/feet)			
	4.28	1.67	>2.58
Bottom Substrate Type			
	silty, clay	vegetated silt	clay, silty
Bank Stability			
	moderately stable	stable	stable
Bank Vegetation Stability			
	moderately vegetated (soils not fully developed)	100% vegetated	100% vegetated
Vegetation Types			
	grasses (terrestrial), some aquatic vegetation	grasses, shrubs, herbaceous plants, filamentous algae, submerged & emergent aquatics	grasses, shrubs, herbaceous plants, filamentous algae, submerged & emergent aquatics
Pond/Ditch Cover			
	open	some	open

TABLE 5. Abundances of benthic macroinvertebrates collected per sample from Vance Branch (Rollem Fork Number 3 Surface Mine; On-Bench Pond Number BP3), 08 October 1999.

TAXON	SAMPLE Ponar 1	Ponar 2	Ponar 3
Insecta			
Diptera (True Flies)			
Ceratopogonidae (T)	8	32	36
Chironomidae (T)	148	648	216
Coleoptera (Beetles)			
Dytiscidae (T)		12	
Laccophilus (T)			12
Hemiptera (Water Bugs)			
Corixidae (T)	4		
Odonata (Dragonflies)			
Coenagrionidae (T)	4	12	4
Collembola (Springtails) (F)	4		
Oligochaeta (Aquatic Worms) (T)	4		
Total Individuals	172	704	268
Taxa	6	4	4

( ) Classification of Pollution Indicator Organisms
(S) = Sensitive (F) = Facultative (T) = Tolerant (U) = Unclassified

TABLE 6. Abundances of benthic macroinvertebrates collected per sample from Rollem Fork (Rollem Fork Number 2 Surface Mine; On-Bench Pond Number 5), 08 October 1999.

TAXON	SAMPLE Ponar 1	Ponar 2	Ponar 3
Insecta			
Ephemeroptera (Mayflies)			
Caenidae			
Caenis (F)	288	112	60
Ephemerellidae			
Ephemerella (F)	64		
Trichoptera (Caddisflies)			
Polycentropodidae (F)	32		
Rhyacophilidae (F)	64		
Diptera (True Flies)			
Ceratopogonidae (T)	64		12
Chironomidae (T)	1088	272	576
Hemiptera (Water Bugs)			
Corixidae (T)		16	4
Odonata (Dragonflies)			
Coenagrionidae (T)	64		8
Gomphidae			
Dromogomphus (T)			4
Libellulidae (T)	32		8
Collembola (Springtails) (F)		16	
Oligochaeta (Aquatic Worms) (T)		16	
smallmouth bass juvenile* (U)			1
Total Individuals	1696	432	672
Taxa	8	5	7

* = Not included in abundance or taxa calculations. For observation only.

( ) Classification of Pollution Indicator Organisms
(S) = Sensitive (F) = Facultative (T) = Tolerant (U) = Unclassified

TABLE 7. Abundances of benthic macroinvertebrates collected per sample from Left Fork of Parker Branch (Pond Number 7), 08 October 1999.

TAXON	SAMPLE Ponar 1	Ponar 2	Ponar 3
Insecta			
Ephemeroptera (Mayflies)			
Baetidae			
Baetis (F)	80	128	64
Caenidae			
Caenis (F)	224	256	192
Trichoptera (Caddisflies)			
Rhyacophilidae (F)		64	
Diptera (True Flies)			
Ceratopogonidae (T)	80	256	80
Chironomidae (T)	240	512	224
Coleoptera (Beetles)			
Amphizoidae (T)		64	
Dytiscidae (T)	16		32
Cybister (T)	8	64	
Haliplidae			
Haliplus (T)	8		
Hemiptera (Water Bugs)			
Mesoveliidae (T)	8	128	
Odonata (Dragonflies)			
Aeshnidae			
Gynacantha (T)		64	
Coenagrionidae (T)	16	64	16
Libellulidae (T)	32	128	
Oligochaeta (Aquatic Worms) (T)	544	832	512
Total Individuals	1256	2560	1120
Taxa	11	12	7

( ) Classification of Pollution Indicator Organisms
(S) = Sensitive (F) = Facultative (T) = Tolerant (U) = Unclassified

TABLE 8. Abundances of benthic macroinvertebrates collected per sample from Vance Branch (Rollem Fork Number 3 Surface Mine; Combination Ditch Number CD3), 08 October 1999.

TAXON	SAMPLE Ponar 1	Ponar 2	Ponar 3
Insecta			
Ephemeroptera (Mayflies)			
Baetidae			
Baetis (F)			4
Diptera (True Flies)			
Ceratopogonidae (T)	12	52	
Chironomidae (T)	56	156	128
Coleoptera (Beetles)			
Amphizoidae (T)		4	
Dytiscidae (T)			
Laccophilus (T)			8
Odonata (Dragonflies)			
Libellulidae (T)	24	4	4
Collembola (Springtails) (F)	4		
Oligochaeta (Aquatic Worms) (T)		4	4
Total Individuals	96	220	148
Taxa	4	5	5

( ) Classification of Pollution Indicator Organisms
(S) = Sensitive (F) = Facultative (T) = Tolerant (U) = Unclassified

TABLE 9. Abundances of benthic macroinvertebrates collected per sample from Rollem Fork (Rollem Fork Number 2 Surface Mine; Sediment Ditch Number SD-3), 08 October 1999.

TAXON	SAMPLE Ponar 1	Ponar 2	Ponar 3
Insecta			
Diptera (True Flies)			
Ceratopogonidae (T)	48	384	16
Chironomidae (T)	256	576	192
Coleoptera (Beetles)			
Hydrophilidae			
Berosus (T)	16		
Oligochaeta (Aquatic Worms) (T)	384	576	128
Total Individuals	704	1536	336
Taxa	4	3	3

( ) Classification of Pollution Indicator Organisms
(S) = Sensitive (F) = Facultative (T) = Tolerant (U) = Unclassified

TABLE 10. Abundances of benthic macroinvertebrates collected per sample from Left Fork of Parker Branch (Sediment Ditch Number 6), 08 October 1999.

TAXON	SAMPLE Ponar 1	Ponar 2	Ponar 3
Insecta			
Ephemeroptera (Mayflies)			
Baetidae			
Baetis (F)	8		
Caenidae			
Caenis (F)	24	64	16
Trichoptera (Caddisflies)			
Polycentropodidae (F)			8
Diptera (True Flies)			
Ceratopogonidae (T)	16	16	8
Chironomidae (T)	112	160	208
Tipulidae			
Tipula (T)		16	
Coleoptera (Beetles)			
Dytiscidae (T)			8
Cybister (T)			
Hemiptera (Water Bugs)			
Mesoveliidae (T)	8	16	
Odonata (Dragonflies)			
Coenagrionidae (T)		64	16
Libellulidae (T)		64	40
Collembola (Springtails) (F)			8
Oligochaeta (Aquatic Worms) (T)	48	16	176
Total Individuals	216	416	488
Taxa	6	8	9

( ) Classification of Pollution Indicator Organisms
(S) = Sensitive (F) = Facultative (T) = Tolerant (U) = Unclassified

APPENDIX C

Photograph 1. Vance Branch (Rollem Fork Number 3 Surface Mine; On-Bench Pond Number BP3).

Photograph 2. Vance Branch (Rollem Fork Number 3 Surface Mine; On-Bench Pond Number BP3).

Photograph 3. Rollem Fork (Rollem Fork Number 2 Surface Mine; On-Bench Pond Number 5).

Photograph 4. Rollem Fork (Rollem Fork Number 2 Surface Mine; On-Bench Pond Number 5).

Photograph 5. Left Fork of Parker Branch (Pond Number 7).

Photograph 6. Left Fork of Parker Branch (Pond Number 7).

Photograph 7. Vance Branch (Rollem Fork Number 3 Surface Mine; Combination Ditch Number CD3).

Photograph 8. Vance Branch (Rollem Fork Number 3 Surface Mine; Combination Ditch Number CD3).

Photograph 9. Rollem Fork (Rollem Fork Number 2 Surface Mine; Sediment Ditch Number SD-3)

Photograph 10. Rollem Fork (Rollem Fork Number 2 Surface Mine; Sediment Ditch Number SD-3)

Photograph 11. Left Fork of Parker Branch (Sediment Ditch Number 6).

Photograph 12. Left Fork of Parker Branch (Sediment Ditch Number 6).

AN EVALUATION OF AQUATIC ECOSYSTEM ENHANCEMENT AT FOUR MOUNTAINTOP MINING/VALLEY FILL SITES IN WEST VIRGINIA

Introduction

The purpose of this report is to present the results of an assessment conducted at four (4) mountaintop mining/valley fill sites in southwestern West Virginia. The assessment focused on evaluating: 1) the effectiveness of current mining and reclamation practices relative to minimizing adverse impacts to stream ecosystems; and 2) the potential for improving current practices to mitigate for unavoidable adverse impacts. The assessment is a component of the Interagency Environmental Impact Statement Technical Study. The assessment involved conducting on-site tours of the four mountaintop mining/valley fill sites, reviewing information/data provided by the mining companies, collecting additional information/data on-site through interviews with mining company staff and field observations of current practices, and photographically documenting those field observations. This assessment did not include detailed monitoring, surveys or field data collection. Information for some sites was unavailable or nonexistent. Where little or no information was available on pre-mining and post-mining conditions the evaluation was based on information gathered from the research literature and field observations. Consequently, the findings may reflect potential, rather than actual differences between pre-mining and post-mining conditions.

Background Information

No information or data is available that characterizes the pre-mining conditions at the four mountaintop mining/valley fill sites. Therefore, the following background information is presented to provide a baseline for comparison to existing conditions. Since the four sites evaluated are all located in the Western Appalachian Plateau physiographic province of West Virginia, the information presented focuses on characteristics of stream ecosystems in this region.

First and second order watersheds/streams and the higher order systems, of which they are an integral component, are dynamic units in the landscape. Within these units the entire complex of interacting physical, chemical and biological processes operate to form a fairly self-supporting ecosystem. Key structural components of these ecosystems include physical characteristics of the watersheds and streams draining them, biological communities, and energy and material resources. Functional components included the physical, chemical and biological processes that affect long-term stability and govern the flow of energy and material through the ecosystems.

First and second order watersheds in the Western Appalachian Plateau are generally characterized by steep, V-shaped valleys. Elevational relief is high, with ridges reaching elevations up to 2000 feet and valley floors situated 400 – 600 feet lower in elevation. The down-valley slopes of these watersheds are often greater than 10% and adjacent hillslopes exceeding 50% are not uncommon. The stream systems exhibit a dendritic pattern. Since the region is a plateau there is no general trend to valley aspect.

Land cover is typically deciduous forest. Depending on historical land use practices, the typical structure of these forests includes a canopy layer of mature trees, an understory layer of smaller trees, a shrub layer, and a groundcover layer. The soil of the forest floor is usually covered with a layer of humus or leaf litter. Although soils may be thinner and/or less permeable in some areas, under these forested conditions organic material, soil microorganisms, and plant roots tend to increase soil porosity and permeability, and stabilize soil structure thereby increasing infiltration rates.

As a consequence of high infiltration rates stream baseflows are fairly reliable, except under drought conditions. Interception of precipitation in the forest canopy, high evapotranspiration rates, and soil condition serve to maintain relatively low surface runoff rates during storm events. Forest cover, litter and the presence of lower vegetation also moderate soil microclimate, in particular the depth and frequency of soil frost. Thus infiltration may occur even during the colder months. The higher infiltration rates and lower runoff rates tend to moderate storm discharge volumes in-channel except during larger, less frequent storm events (RI: 50 – 100 YRS). In lower reaches where valley floors are wider, floodplains have developed. These areas serve to detain floodwaters that overtop the channel banks, thereby extending the time of concentration and moderating the effects of these flows on downstream reaches. In some watersheds these floodplain areas support wetland communities, particularly where groundwater discharges at the base of hillslopes.

Due to vegetative cover, stable soil structure, and low runoff rates, soil erosion and sediment transport from upland areas is minimal. The stabilizing effect of vegetation and moderate storm flow volumes result in relatively small inputs of sediment from in-channel sources as well.

The morphologic characteristics of stream channels in these first and second order watersheds vary in confinement, slope, bed features, and bed materials. Steeper reaches are characterized as a cascading or step-pool morphology with irregularly spaced drops and scour pools. The spacing of these features is highly irregular and is controlled by bedrock and large woody debris (LWD). These channels are entrenched (< 1.4) and confined between adjacent hillslopes. Width/depth ratios are low (< 12). Channel gradient can range 4% to 10+%. These channels are relatively straight with sinuosities less than 1.2. Reaches with these characteristics correspond to the A and Aa+ stream types presented in A Classification of Natural Rivers (Rosgen, 1994).
Moderate gradient reaches, 2-4%, usually exhibit riffle-scour pool or rapid-scour pool morphology. At the steeper end of this gradient range they may transition into step-pool morphology. These reaches are characterized by moderate entrenchment (1.4 – 2.2) and a wider valley floor. The valley floor will function as a floodplain for storm flows greater than bankfull and may support wetland communities. Width/depth ratios greater than 12. Channel sinuosity is not high (1.1 – 1.5) but is greater than the A stream types. These channels correspond to B stream types (Rosgen, 1994). Flatter gradient reaches (i.e., less than 2%) are usually not entrenched and may have a well developed floodplain that supports wetland communities. Width to depth ratios are high (> 12). Sinuosity is also higher (1.2 – 2.1) than the steeper A and B stream reaches. These channels correspond to C stream types (Rosgen, 1994). Channel materials in the Aa+, A, B and C stream types vary depending on the lithography of the watershed. In this region headwater reaches most commonly exhibit boulder or cobble beds with lesser amounts of gravels, sands or silts. Bedrock reaches are interspersed throughout. The geometry and dimensions of these channels have been shaped and maintained by the bankfull discharges that occur on roughly an annual basis (RI: 1 – 2 YRS). As indicated previously, the volume of these storm flows is moderated by the forested conditions typical of these watersheds.

The physicochemical properties (e.g., temperature, pH, dissolved gases, and dissolved and suspended organic and inorganic compounds) of the water flowing in these streams are influenced by many factors. In headwater streams, weathering and dissolution of rock is commonly the major determinant of stream water chemistry. However, land use is also a significant factor. For example, in forested watersheds reduced insolation moderates the diel and annual range and seasonal minimum-maximum stream temperatures. Water temperature, in turn, affects the solubility of dissolved gases and solids, as well as the rate of chemical reactions. Litterfall and the decomposition of plant and animal material in forested watersheds are a source of inorganic nutrients that are transported to the stream via throughflow of infiltrated rain and groundwater discharge.

In headwater streams, it is generally recognized that allochthonous material (i.e., leaves, needles, and woody debris falling or blown into the stream from the adjacent forest) and autochthonous sources (i.e., periphyton) are important sources of simple carbon compounds and that they complement one another seasonally. However, forested stream systems are primarily heterotrophic (i.e., rely primarily on allochthonous material) as an energy source. Although autotrophic production is provided by periphytic diatoms, standing biomass is usually kept low by stream scour, invertebrate grazing, and forest shade. Therefore, the ratio of autotrophic production to heterotrophic respiration (P:R) is low (<1).

Consequently, large particulate shredders (e.g., Trichoptera, Plecoptera, Coleoptera, Diptera) and fine particulate collectors-gatherers (e.g., Ephemeroptera, Chironomidae, and Ceratopogonidae) are co-dominant in the macroinvertebrate community of headwater streams. Periphyton grazers (e.g., Ephemeroptera, Trichoptera, Diptera, Lepidoptera, and Coleoptera) and predators (e.g., Megaloptera, Plecoptera, Trichoptera, and Odonata) make up smaller percentages of this community. Primary production provided by algae and macrophytes and a macroinvertebrate community with a large percentage of collector-filterers (e.g., Trichoptera, Diptera, and Ephemeroptera) are more typically associated with higher order reaches where there is less shade, slower moving water, and fine particulate organic matter is transported in suspension. Fish species in these headwater streams are generally those adapted to cold or cool, swift flowing water, with moderately high – high dissolved oxygen concentrations. Benthic invertebrate feeders and too a lesser extent piscivores are the most representative trophic guilds of the fish community.

To contribute energy to the food web of the stream reach, organic material (i.e., leaves, needles, twigs) must be retained in the channel where it can be processed. Therefore, retention and export determine the contribution of organic matter to the stream system. Small headwater stream systems are generally efficient at retaining coarse particulate organic material (CPOM) and processing it to fine particulate organic matter (FPOM) and dissolved organic matter (DOM). Interstices in the streambed and roughness elements, such as boulders and large woody debris in the channel, promote retention. Export of organic matter depends on the hydraulic power of the stream, size of the particle, and retentive capacity of the channel.

Methodology

The first part of the assessment involved the evaluation of current practices relative to minimization of adverse impacts to the stream ecosystems via avoidance or mitigation (i.e., restoration or replacement of structure and function). Evaluating complex natural systems and the effects of alterations to one or more of their components is a difficult task. Although the limitations outlined in the *Introduction* precluded a more detailed assessment, to the extent practical a number of considerations were incorporated into the evaluation process. Based on the characterization of first and second order watersheds/stream ecosystems presented in the *Background Information* a number of relevant questions were postulated. The answers to these questions are presented as findings in this report.

1. Are the watershed/valley characteristics consistent with pre-mining conditions?
2. Is the vegetative cover consistent with pre-mining conditions?
3. Have the soil characteristics been modified?
4. Has the hydrologic regime been altered?
5. Has the sediment regime been modified?
6. Is channel morphology consistent with a natural, stable channel form?
7. Have the physicochemical properties of the streams been altered?
8. Have the biotic communities, trophic structure, and energy sources of the stream ecosystems changed?

Although not included in this evaluation, these same questions should be posed relative to the degree to which current mining and reclamation practices have altered or maintained the natural (pre-mining) structure and function of the higher order watershed/stream ecosystems to which these sites drain.

The second part of the assessment involved identifying opportunities for modifying current practices or implementing new approaches that would minimize the adverse impacts of the mining operations. These are presented as recommendations in this report.

Assessment Results

1. Elk Run Coal Company
East of Stollings Surface Mine

a. General

This mine is located south of the town of Racine, West Virginia. The site has been mined since 1987. The operations on this site consist of surface mining of ridge tops with shovel and truck and loader. The streams draining the site include first and second order tributaries to Mudlick Fork and Stollings Fork, which are part of the Laurel Creek/Big Coal River/Kanawah River drainage system. The mining operation will produce approximately 250 million cubic yards of overburden. Roughly 34.8% (86.2 million cubic yards) of that material will be disposed of in the seven (7) proposed valley fills. The valley fills are composed of durable rock fill built in 50 to 100 foot lifts.

Stormwater runoff conveyance and sediment control are provided for via a network of perimeter sediment ditches, groin ditches, and sedimentation ponds. This network is designed to convey all storm flows up to and including the 100-year runoff event and sediment that is eroded and transported from exposed surfaces. The perimeter ditches collect and convey stormwater flow across the face of the valley fill. Although the dimensions of the ditches vary with drainage area, they are usually constructed on 20 - 30 foot wide benches and have a relatively flat gradient. They are stabilized with a grass mix. Groin ditches convey stormwater flow down the face of the valley fill. They are usually 10 – 15 feet wide. Although breaks in slope occur at the benches where the perimeter ditches contribute their flow, the groin ditches are generally very steep. Groin ditches are lined with large rock to provide stabilization. Sedimentation ponds are constructed at the base of the valley fill to capture and retain sediment transported off the exposed valley fill or active mining areas. The ponds are sized to manage the entire valley fill area. Since baseflow from the streams buried beneath the valley fill discharges into the ponds they retain a permanent pool. The ponds outfall immediately upslope from the receiving streams, Mudlick Fork and Stollings Fork.

b. Evaluation of Current Practices

1. Watershed/Valley Characteristics

The watershed impacted by Valley Fill #3 provides an example of how the mining operation and reclamation will alter the watershed/valley characteristics at this site. The pre-mining difference in elevational relief from the ridgelines to the valley floors was fairly significant. The elevations of the ridgelines ranged from 1800 - 1900 feet while the elevation of the valley floor at its confluence with Mudlick Fork was 1150 feet, an elevational difference of as much as 750 feet. The watershed is being reconstructed with flat or broadly rounded ridgelines, lower in elevation, and a broad valley floor, higher in elevation. Consequently, the elevational difference between the ridgelines and new valley floor will be 100 – 150 feet

Although the overall valley slope of the watershed was greater than 10%, pre-mining the down-valley profile included areas of varying slopes. Some valley reaches were very steep, while other reaches had a fairly gentle slope. Current reclamation practices have created a down valley slope that is uniformly moderate (4%) along the top of the fill and uniformly steep (80%) down the face of the fill.

The pre-mining cross-section of the valley also exhibited variability. Hillslopes were characterized by natural breaks where the form and gradient of the slopes changed from steep and convex to relatively gentle and concave and back to steep and convex. As pointed out above, ridgelines have been constructed to recreate the natural landform. Unfortunately this effort falls short across the top of the valley fill and down the face of the fill, where form is still linear and slopes uniform.

These modifications have reduced the size of the drainage area. The drainage pattern will be altered and more closely resemble a modified trellis. Although the watershed will still trend northwest southeast, its aspect relative to the prevailing winds, precipitation, and insolation will be altered due to the changes in valley form.

2. Vegetative Cover

On this site all vegetation was cleared and grubbed prior to the mining operation commencing. Reclaimed areas were seeded with a grass mix, which included K-31. A few areas have been sparsely planted with one or two species of trees. However, at the time of the tour most stabilized areas were covered with grasses and a few widely scattered volunteer shrubs. The remnant forests on site were isolated on undisturbed hillslopes adjacent to sedimentation ponds along Mudlick Fork and Stollings Fork, and as yet unmined ridgelines.

3. Soil Characteristics

The valley fill is a durable rock fill laid down in lifts. The native topsoil and subsoil layers were removed as part of the mining operation. They were not separated and stockpiled for reuse during reclamation. The material laid down during reclamation is a coarse mixture of rock and other overburden material (e.g., sandstone, limestone, clay, shale, subsoils). This valley fill material has a very high percentage of mineral soil and very low percentage of organic matter. As such it will make a very poor growth medium for reestablishing a forest. No information was available regarding its permeability or infiltration rates. However, since this unconsolidated material is composed of varying types of rock and soil, it is likely that some areas will be permeable and other areas impermeable. Another factor affecting the permeability of this material is mechanical compaction of the fill surface by heavy equipment.

4. Hydrologic Regime

In the areas toured it appeared that baseflows are still flowing along the old valley floor, emerging at the base of the valley fill into the sedimentation ponds. The perimeter sediment ditches and groin ditches carry flow during and immediately after storm events. There is no baseflow in these channels. Although no data was available relative to the volume and time of concentration of storm flows, based on the characteristics of the fill material, compaction of the fill surface, and a relatively sparse vegetative cover, it is likely that the volume of runoff is significantly greater than under pre-mining conditions. It is also likely that the time of concentration for these flow events has been reduced with the potential to effect downstream reaches. The perimeter ditches and sedimentation ponds help detain runoff and may provide some management for the increased runoff.

5. Sediment Regime

No data was available to allow a quantitative comparison of erosion and sediment transport rates. However, it is likely that erosion and sediment transport rates from upland sources (i.e., active mining areas, valley fill areas, and adjacent disturbed areas) are significantly higher than pre-mining conditions. However, it appears that disturbed areas routed to the perimeter ditch/groin ditch/sedimentation pond systems are being managed effectively thereby limiting actual sediment loadings to the receiving streams. Erosion of channel bed and banks in receiving streams adjusting to increased storm flows could provide an unmanaged source of sediment to downstream reaches.

6. Channel Morphology

Based on a review of the site map provided, it appears that approximately 10,500 feet of the first and second order streams on site have been permanently impacted by valley fill. Another 3500 feet of stream channel has been temporarily impacted for construction of access roads, and sedimentation ponds.

The morphology of the perimeter ditches and groin ditches are consistent with that of engineered drainage-ways, not natural stream channels. The perimeter ditches are wide, trapezoidal, and relatively flat. The groin ditches are also trapezoidal but very steep (80%). There are no discernible bed features (i.e., step-pools or riffle-pools). Since the channels are designed to convey runoff from larger storm events all flows are confined to that one channel. Consequently, there are no natural channels with typical baseflow and bankfull channels and an adjacent floodprone bench or floodplain. However, it should be noted that the constructed channels appeared to be stable and functioning as designed.

7. Physicochemical Properties

The Elk Run Coal Company collected water quality data in the Spring, Summer, and Fall of 1999. Although that data was unavailable for this assessment, water quality data collected from streams draining similar surface mining/valley fill operations may apply to this site. On the sites they were monitoring, Maggard and Kirk (1998) found that several water quality parameters varied from pre-mining levels. Their data indicates that conductivity, total dissolved solids, hardness, alkalinity, sulfates, sodium, calcium, and magnesium levels had increased significantly.

R.E.I. Consultants, Inc. (1999) evaluated the water quality of sedimentation ponds constructed on similar mining sites. They found that water quality varied considerably with the age of the facilities. For example, pH ranged from 5.04 - 8.77, in newer and older ponds respectively. They reported that most of the chemical values (e.g., dissolved solids, hardness, alkalinity, sulfates, and most metals) were initially fairly high, diminishing somewhat with the age of the structure. Their data may apply to the ponds on this site.

8. Biotic Communities, Trophic Structure, and Energy Sources

The Elk Run Coal Company collected biological data in the Spring, Summer, and Fall of 1999. Although that data was unavailable for this assessment, biological data collected from streams draining similar surface mining/valley fill operations may apply to this site. On the sites they monitoring, Maggard and Kirk (1998) found that the benthic macroinvertebrate community downstream of mining/valley fill operations shifted toward more pollution tolerant species. Their data indicates that the number of individuals and taxa richness increased, while diversity and evenness decreased.

R.E.I. Consultants, Inc. (1999) evaluated the biological communities in sedimentation ponds constructed on other similar mining sites. They found that the biotic communities developing in the sedimentation ponds include species typical of a lentic ecosystem. Macrophytes and filamentous algae provide primary production. Allochthonous material enters these sites as litterfall from forests on adjacent hillslopes.

The benthic macroinvertebrate community is composed of typical pond species (e.g., Diptera, Coleoptera, Hemiptera, Odonata, and Oligochaeta). The communities in the newer facilities exhibited low abundance and diversity, and were represented predominantly by very pollution tolerant species. The older facilities, where water quality was better and vegetation was abundant, exhibited higher abundance and diversity. Species present were still primarily pollution tolerant organisms. The fish community was not represented in the ponds. In the short-term at least, it is not likely that these structures will provide habitat for amphibians since most amphibian species are very sensitive to poor water quality.

Elk Run Coal Company's East of Stollings Surface Mine

Looking across valley fill toward active mining area.

Active mining area with adjacent reclaimed area. Photo taken from valley fill looking toward sedimentation pond.

Older (pre-1994) reclaimed area. Valley fill with groin ditch to perimeter ditch.

More recent (post-1994) reclaimed area. Valley fill with perimeter ditches and groin ditches to convey runoff from slopes.

Active valley fill with perimeter ditches across face of fill.

Sedimentation ponds at base of valley fill. Photo shows undisturbed slopes on both sides and perimeter ditch in fill to left.

Groin ditch to perimeter sedimentation ditch in older area.

Photo shows sedimentation ditch at older site.

Outfall control structure for sedimentation ditch

2. Catenary Coal Company
Samples Surface Mine

a. General

This mine is located near the town of Eskdale, West Virginia. Catenary Coal Company acquired the site in 1989 and the current expansion commenced in 1993. The operations on this site consist of dragline surface mining of ridge tops. The streams draining the site include first and second order tributaries to Cabin Creek and White Oak Creek/Big Coal River, which are in the Kanawah River drainage system. In 1998 the mining operation moved 80 million bank cubic yards of material. Roughly 25% (20 million loose cubic yards) of that material was disposed of in valley fills. The valley fills are composed of durable rock fill built in 50 to 100 foot lifts.

Stormwater runoff conveyance and sediment control are provided for via a network of combination ditches, groin ditches, and sedimentation ponds. This network is designed to convey all storm flows up to and including the 100-year runoff event and sediment that is eroded and transported from exposed surfaces. The combination ditches collect and convey stormwater flow across the top of the valley fill. The combination ditches are 10 – 15 feet wide across the bottom and have a relatively flat gradient. They were stabilized with a grass mix. Groin ditches convey stormwater flow down the face of the valley fill. They are usually 10 – 15 feet wide. Although breaks in slope occur at the benches, the groin ditches are generally very steep. Groin ditches are lined with large rock to provide stabilization. Sedimentation ponds were constructed at the top and base of the valley fill to capture and retain sediment transported off the exposed valley fill or active mining areas. The ponds are sized to manage the entire area draining to them. Some of the ditches intercept groundwater at the back edge of the cut along the down dip side of the valley fill and therefore carry a baseflow. Where this baseflow discharges into the sedimentation ponds they retain a permanent pool.

c. Evaluation of Current Practices

1. Watershed/Valley Characteristics

The pre-mining difference in elevational relief from the ridgelines to the valley floors was fairly significant. The surface mining/valley fill significantly reduced the elevational difference between the original ridgelines and valley floors. However, contour/landform grading and backstacking of overburden to heights of 300 feet has restored some of the relief and recreated ridgelines.

Although the overall valley slope of the watershed was greater than 10%, pre-mining the down-valley profile included areas of varying slopes. Some valley reaches were very steep, while other reaches had a fairly gentle slope. Current reclamation practices have created a down valley slope that is uniformly moderate along the top of the fill and uniformly steep down the face of the fill.

The pre-mining cross-section of the valley also exhibited variability. Hillslopes were characterized by natural breaks where the form and gradient of the slopes changed from steep and convex to relatively gentle and concave and back to steep and convex. As pointed out above, ridgelines have been constructed to recreate the natural landform. Unfortunately this effort falls short across the top of the valley fill and down the face of the fill, where form is still linear and slopes uniform.

These modifications have reduced the size of the drainage area. The drainage patterns have been altered and more closely resemble a modified trellis. As result of the changes in landform, the watershed aspect relative to prevailing winds, precipitation, and insolation has been altered.

2. Vegetative Cover

On this site all vegetation was cleared and grubbed prior to the mining operation commencing. Reclaimed areas were seeded with a grass mix, which included K-31. A few areas have been sparsely planted with one or two species of trees. However, at the time of the tour most stabilized areas were covered with grasses and a few widely scattered volunteer shrubs. The remnant forests on site were isolated on undisturbed hillslopes adjacent to downstream reaches and unmined ridgelines.

3. Soil Characteristics

The valley fill is a durable rock fill laid down in lifts. The native topsoil and subsoil layers were removed as part of the mining operation. They were not separated and stockpiled for reuse during reclamation. The material laid down during reclamation is a coarse mixture of rock and other overburden material (e.g., sandstone, limestone, clay, shale, subsoils). This valley fill material has a very high percentage of mineral soil and very low percentage of organic matter. As such it will make a very poor growth medium for reestablishing a forest. No information was available regarding its permeability or infiltration rates. However, since this unconsolidated material is composed of varying types of rock and soil, it is likely that some areas will be permeable and other areas impermeable. Another factor affecting the permeability of this material is mechanical compaction of the fill surface by heavy equipment.

4. Hydrologic Regime

Some of the combination ditches intercept groundwater at the back edge of the cut along the down dip side of the valley fill and therefore carry a baseflow. In the areas toured the baseflows are maintaining a permanent pool in sedimentation ponds and supporting wetland vegetation around the margins of the pond and in the ditches. Reclamation of the Kayford Refuse Pile along Tenmile Fork was completed in 1999. This reclamation included construction of a series of ponds, artificial wetland systems, and a channel that conveys baseflow and stormflow.

Although no data was available relative to the volume and time of concentration of storm flows, based on the characteristics of the fill material, compaction of the fill surface, and a relatively sparse vegetative cover, it is likely that the volume of runoff is significantly greater than under pre-mining conditions. It is also likely that the time of concentration for these flow events has been reduced with the potential to effect downstream reaches. The combination ditches and sedimentation ponds help detain runoff and therefore may be providing some management for the increased storm flows.

5. Sediment Regime

No data was available to allow a quantitative comparison of erosion and sediment transport rates. However, it is likely that erosion and sediment transport rates from upland sources (i.e., active mining areas, valley fill areas, and adjacent disturbed areas) are significantly higher than pre-mining conditions. However, it appears that disturbed areas routed to the combination ditch/groin ditch/sedimentation pond systems are being managed effectively thereby limiting actual sediment loadings from the site to the receiving streams. Increased storm flows from the site could contribute to channel adjustment and instability of downstream reaches, thereby creating a potential source of uncontrolled sediment.

6. Channel Morphology

No information was available to determine the linear feet of stream channel impacted by the valley fills. However, given the size of the fill areas observed on site it appears that major sections (i.e., several miles) of the first and second order streams on site have been impacted by valley fill or the construction of the sedimentation ponds.

The morphology of the combination ditches and groin ditches are consistent with that of engineered drainage-ways, not natural stream channels. The perimeter ditches are wide, trapezoidal, and relatively flat. The groin ditches are also trapezoidal but very steep. The one combination ditch observed during the tour along the top of the fill appeared to be developing discernible bed features (i.e., riffle and pools). However, since the channels are designed to convey runoff from larger storm events all flows are confined to that one channel. Consequently, there are no bankfull channels with an adjacent floodplain. It should be noted that the engineered channels constructed along the top and down the face of the valley fill appeared to be stable and functioning as designed.

The channel constructed at the Kayford Reclamation site is also an engineered channel. It has two distinct reaches. The upper reach starts at the base of the large sedimentation pond. This reach is wide, trapezoidal, relatively flat and entrenched. It appeared to be lined with a geotextile erosion control fabric. Given its dimensions, it is obviously designed to carry fairly significant storm flows. Unfortunately, because it is entrenched there is no floodplain surface to convey the high flows. During high flows channel velocities and shear stresses will be considerable. This situation could affect the long-term stability of the reach. The lower reach is also wide and trapezoidal, but very steep. This section is lined with geotextile fabric and rock. During the tour of this area, it was observed that the bed of the lower reach is incising immediately downstream of the break in slope between the upper and lower reach and a headcut is eroding into the upper reach. This unstable condition is probably the result of a number of interrelated factors, including the unusually high shear stresses generated through the entrenched upper reach and at the point where the slope suddenly increases at the upstream end of the lower reach, the morphology of the channel in the steep reach, the size of rock used to stabilize the reach, and flow eroding material from beneath the fabric. The natural reach immediately downstream exhibited heavy sedimentation. If not corrected, the headcut will continue upstream, destabilizing the upper reach.

7. Physicochemical Properties

Although no water quality data was available for this assessment, Maggard and Kirk (1998) monitoring streams draining similar mining/valley fill operations found that several water quality parameters had varied from pre-mining levels. Their data indicates that conductivity, total dissolved solids, hardness, alkalinity, sulfates, sodium, calcium, and magnesium had increased significantly. Their findings may apply to the receiving streams on this site.

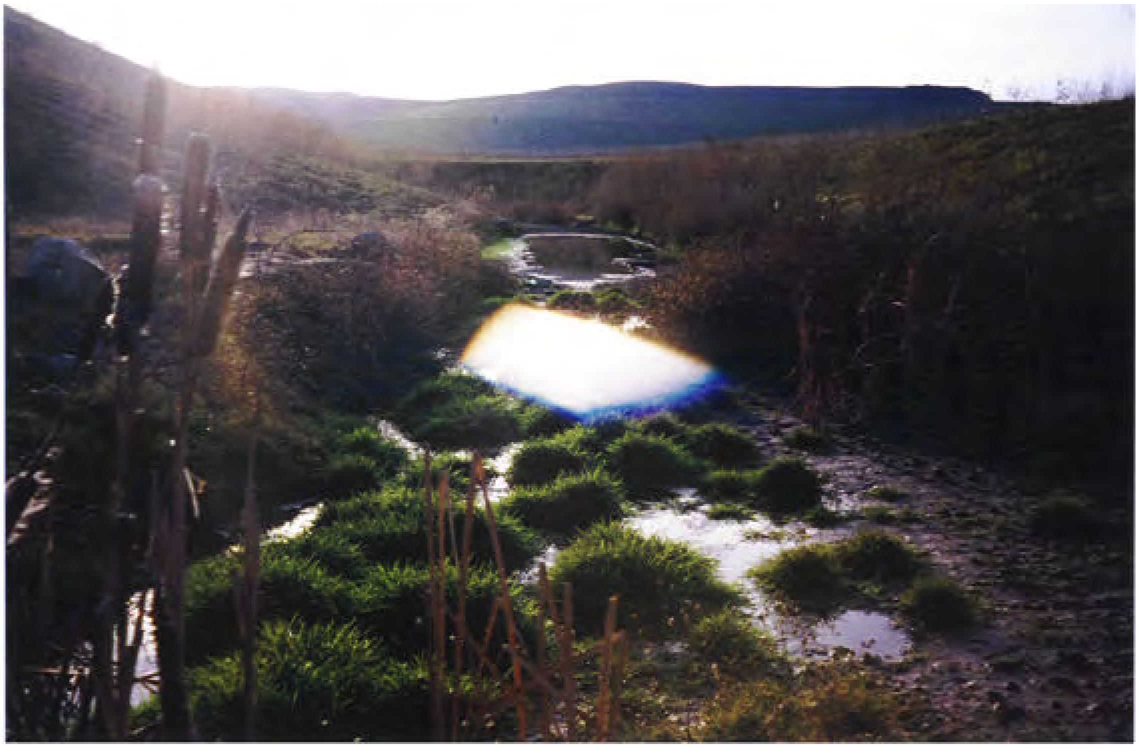
R.E.I. Consultants, Inc. (1999) evaluated the water quality of sedimentation ponds constructed on similar mining sites. They found that water quality varied considerably with the age of the facilities. For example, pH ranged from 5.04 - 8.77, in newer and older ponds respectively. They reported that most of the chemical values (e.g., dissolved solids, hardness, alkalinity, sulfates, and most metals) were initially fairly high, diminishing somewhat with the age of the structure. These findings may apply to the ponds on this site.

8. Biotic Communities, Trophic Structure, and Energy Sources

No biological data was available for this assessment. However, Maggard and Kirk (1998) monitoring streams below similar mining/valley fill operations found that the benthic macroinvertebrate community shifted toward more pollution tolerant species. Their data indicates that the number of individuals and taxa richness increased, while diversity and evenness decreased. These findings may apply to the tributaries of Cabin Creek and White Oak Creek.

R.E.I. Consultants, Inc. (1999) evaluated the biological communities in sedimentation ponds constructed on similar mining sites. The biotic communities that have developed in these facilities include species typical of a lentic ecosystem. Macrophytes and filamentous algae provide primary production. Allochthonous material enters these sites as litterfall from forests on adjacent hillslopes.

The benthic macroinvertebrate community is composed of typical pond species (e.g., Diptera, Coleoptera, Hemiptera, Odonata, and Oligochaeta. The communities in the newer facilities exhibited low abundance and diversity, and were represented predominantly by very pollution tolerant species. The older facilities, where water quality was better and vegetation was abundant, exhibited higher abundance and diversity. Species present were still primarily pollution tolerant organisms. The fish community was not represented in the ditches and ponds. It is not likely that these structures will provide habitat for amphibians since most amphibian species are very sensitive to poor water quality.



Ditch draining upper sedimentation pond.

Ditch draining upper sedimentation pond

On-line sedimentation pond downstream of valley fill

Concrete spillway of on-line sedimentation pond

Wetland ponds downstream of sedimentation pond. Photo shows runoff ditch to right of wetland ponds. This ditch conveys baseflow and stormflows.

Runoff ditch along right valley wall adjacent to wetland ponds

Headcut erosion at break in slope at downstream end of runoff ditch

Headcut erosion working upstream through steep section of runoff ditch

Heavy sedimentation in receiving stream below runoff ditch

Heavy sedimentation in receiving stream below runoff ditch

3. Pen Coal Corporation
Kiah Creek Mine

a. General

This mine is located near the town of Ferrellsburg, West Virginia. The operations at this site consist of ridgetop and contour surface mining utilizing truck and loader methods. The streams draining the site include first and second order tributaries to Vance Branch of Trough Fork and Rollem Fork of Kiah Creek, which are part of the East Fork of Twelvepole Creek drainage system. The mining operation will produce approximately 360 million cubic yards of overburden. Approximately 25% (9 0 million cubic yards) of that material will be disposed of in the proposed valley fills. The valley fills are composed of durable rock fill built in 50 to 100 foot lifts.

Stormwater runoff conveyance and sediment control are provided for via a network of combination ditches, groin ditches, and sedimentation ponds. This network is designed to convey all storm flows up to and including the 100 year runoff event and sediment that is eroded and transported from exposed surfaces. The combination ditches collect and convey stormwater flow around the perimeter of the valley fill. Although the dimensions of the ditches vary with drainage area, they are commonly constructed with 10 - 15 foot bottom widths and 6 – 8 foot depth. They have a relatively flat gradient and stone weirs are spaced regularly along the ditches to improve sedimentation rates. The ditches are stabilized with a grass mix. Groin ditches convey stormwater flow down the face of the valley fill. They are usually 10 – 15 feet wide. Although, breaks in slope occur at the benches where the perimeter ditches contribute their flow, the groin ditches are generally very steep. Groin ditches are lined with large rock to provide stabilization. Sedimentation ponds are constructed on the benches along the valley fill and at the base of the valley fill to capture and retain sediment transported off the exposed valley fill or active mining areas. The ponds are sized to manage the entire disturbed area. Some of the ditches intercept groundwater at the back edge of the cut along the down dip side of the valley fill and therefore carry a baseflow. Where this baseflow discharges into the sedimentation ponds they retain a permanent pool. In other areas baseflow from the streams buried beneath the valley fill discharges into the ponds providing a permanent pool. Such is the case with the ponds that outfall immediately upslope from the receiving streams, Vance Branch and Rollem Fork.

d. Evaluation of Current Practices

1. Watershed/Valley Characteristics

In the areas toured the majority of the operations were contour mining. Ridgetop mining made up only a small percentage of the overall mining activity. Consequently, the amount of valley fill and disturbance to ridgelines was significantly less than observed on other mining sites where ridgetop mining made up the larger percentage of the operations.

The pre-mining difference in elevational relief from the ridgelines to the valley floors was fairly significant. In areas of ridgetop mining/valley fill the elevational difference between the original ridgelines and valley floors fill have been significantly reduced. Contour grading and backstacking of overburden has restored some of the relief.

Although the overall valley slope of the watershed was greater than 10%, pre-mining the down-valley profile included areas of varying slopes. Some valley reaches were very steep, while other reaches had a fairly gentle slope. In the valley fill areas, current reclamation practices have created a down valley slope that is uniformly moderate along the top of the fill and uniformly steep down the face of the fill.

The pre-mining cross-section of the valley also exhibited variability. Hillslopes were characterized by natural breaks where the form and gradient of the slopes changed from steep and convex to relatively gentle and concave and back to steep and convex. Reconstructed landform is still predominantly linear on this site.

2. Vegetative Cover

On this site clearing and grubbing of vegetation was mostly restricted to the areas to be mined. Consequently, the undisturbed ridgelines and hillslopes above and below the areas of contour mining are still heavily forested. Recently reclaimed areas along Vance Branch and Rollem Fork were seeded with a grass mix and appeared to have a dense grass cover. Some unmined valley floor areas were cleared to accommodate construction of access roads, sedimentation ponds, relocation of the stream channel, and floodplain fill. These areas were seeded with a grass/clover mix and appeared to have a dense grass cover.

A reclamation site along Frank's Branch was toured to observe a reforestation effort that was completed 10 years ago. One area appeared to be progressing very well. In addition to the initial plantings, it was evident that volunteer species were doing well. This has probably increased overall diversity of this early-successional vegetative community. The overall vegetation was dense enough, even without foliage, to make it difficult to determine the location of the groin ditch routed down the face of the valley fill. Interestingly, an area immediately adjacent on the same slope had experienced rill and gully erosion immediately after reclamation. The area had been repaired, stabilized with a grass mix (that included K-31) and reforested. Although, the two areas were the same age, this slope area was still covered in grass with only a few widely scattered shrubs.

3. Soil Characteristics

The valley fill is a durable rock fill laid down in lifts. The native topsoil and subsoil layers were removed as part of the mining operation. They were not separated and stockpiled for reuse during reclamation. The material laid down during reclamation is a coarse mixture of rock and other overburden material (e.g., sandstone, limestone, clay, shale, subsoils). This valley fill material has a very high percentage of mineral soil and very low percentage of organic matter. Because this material makes a very poor growth medium for reestablishing a forest a 6-inch layer of topsoil is added overall reclaimed areas. No information was available regarding permeability or infiltration rates of the valley fill material. However, Mr. Randy Maggard (personal communication) characterized this unconsolidated material as a "psuedo-karst" landscape, composed of varying types of rock and soil that will be permeable in some areas and impermeable in others. Another factor affecting the permeability of the fill material is mechanical compaction of the fill surface by heavy equipment.

4. Hydrologic Regime

Some of the combination ditches intercept groundwater at the back edge of the cut along the down dip side of the valley fill and therefore carry a baseflow. These ditches support wetland vegetation. The baseflows are also maintaining a permanent pool in all the sedimentation ponds observed. Many of the ponds exhibited a dense growth of wetland vegetation around their margins. Although no data was available relative to the volume and time of concentration of storm flows, based on the characteristics of the fill material, compaction of the fill surface, and a relatively sparse vegetative cover, it is likely that the volume of runoff is significantly greater than under pre-mining conditions. It is also likely that the time of concentration for these flow events have been reduced with the potential to affect downstream reaches. The combination ditch/groin ditch/sedimentation pond systems help detain runoff and therefore may be providing some management for the increased storm flows.

5. Sediment Regime

No data was available to allow a quantitative comparison of erosion and sediment transport rates. However, it is likely that erosion and sediment transport rates from upland sources (i.e., active mining areas, valley fill areas, and adjacent disturbed areas) are significantly higher than pre-mining conditions. However, it appears that disturbed areas routed to the combination ditch/groin ditch/sedimentation pond systems are being managed effectively thereby limiting actual sediment loadings to the receiving streams. Erosion of the stream bed and banks in areas that adjust to accommodate the increased storm flow volumes provides a potential unmanaged source of sediment to downstream reaches.

6. Channel Morphology

Based on a review of the site maps provided, it appears that approximately 8000 linear feet of first and second order streams were permanently impacted by valley fill in the Rollem Fork area. Another 3200 linear feet stream channel (and adjacent floodplain) of Rollem Fork have been temporarily impacted for the construction and maintenance of the sedimentation ponds. It is important to note that the contour mining operations on this site have significantly reduced the potential impact on the Rollem Fork system relative to the impacts observed at other sites where ridgetop mining operations dominate.

The morphology of the combination ditches and groin ditches are consistent with that of engineered drainage-ways, not natural stream channels. The combination ditches are wide, trapezoidal, and relatively flat. The groin ditches are also trapezoidal but very steep. There are no discernible bed features (i.e., riffle-pools) in the combination ditches. However, several of the groin ditches appeared to be developing a step-pool morphology. Since the channels are designed to convey runoff from larger storm events all flows are confined to that one channel. They were not designed to have a baseflow, and bankfull channel with and adjacent floodplain. It should be noted that the constructed channels appeared to be stable and functioning as designed.

7. Physicochemical Properties

Pen Coal Company at their mining sites has collected stream and pond water quality data. Although no stream data was available for the sites evaluated in this assessment, Maggard and Kirk (1998) monitoring streams draining other Pen Coal mining sites found that several water quality parameters had varied from pre-mining levels. Their data indicates that conductivity, total dissolved solids, hardness, alkalinity, sulfates, sodium, calcium, and magnesium had increased significantly. These trends in water quality may apply to the receiving streams on this site as well.

R.E.I. Consultants, Inc. (1999) evaluated the water quality of combination ditches and sedimentation ponds constructed in the Vance Branch, Rollem Fork, and the Left Fork of Parker Branch drainage basins. Water quality varied considerably between the sampling sites. For example, pH ranged from 5.04 - 8.77 in the ponds and from 5.32 – 9.39 in the combination ditches. They found that most of the chemical values (e.g., dissolved solids, hardness, alkalinity, sulfates, and most metals) were high. They found that water quality improved with the age of the structure.

8. Biotic Communities, Trophic Structure, and Energy Sources

Pen Coal Company has collected a considerable amount of stream and pond biological data at their mining sites. Although no stream data was available for the sites evaluated in this assessment, Maggard and Kirk (1998) found that the benthic macroinvertebrate communities downstream of mining/valley fill operations shifted toward more pollution tolerant species. Their data indicates that the number of individuals and taxa richness increased, while diversity and evenness decreased. These findings may apply to Rollem Fork and Vance Branch.

R.E.I. Consultants, Inc. (1999) evaluated the biological communities in the combination ditches and sedimentation ponds constructed in the Vance Branch, Rollem Fork, and the Left Fork of Parker Branch drainage basins. The biotic communities that have developed in the combination ditches and sedimentation ponds include species typical of a lentic ecosystem. Macrophytes and filamentous algae provide primary production. Allochthonous material enters these sites as litterfall from forests on adjacent hillslopes.

The benthic macroinvertebrate community is composed of typical pond species (e.g., Diptera, Coleoptera, Hemiptera, Odonata, and Oligochaeta. The communities in the newer facilities exhibited low abundance and diversity, and were represented predominantly by very pollution tolerant species. The older facilities, where water quality was better and vegetation was abundant, exhibited higher abundance and diversity. Species present were still primarily pollution tolerant organisms. The fish community was not represented in the ditches and ponds. It is not likely that these structures will provide habitat for amphibians since most amphibian species are very sensitive to poor water quality.

Combination ditch with ponded baseflow

Outfall of combination ditch. Baseflow has gone subsurface into valley fill.

Combination ditch with baseflow supporting wetland vegetation

Wetland vegetation and filamentous algae in combination ditch

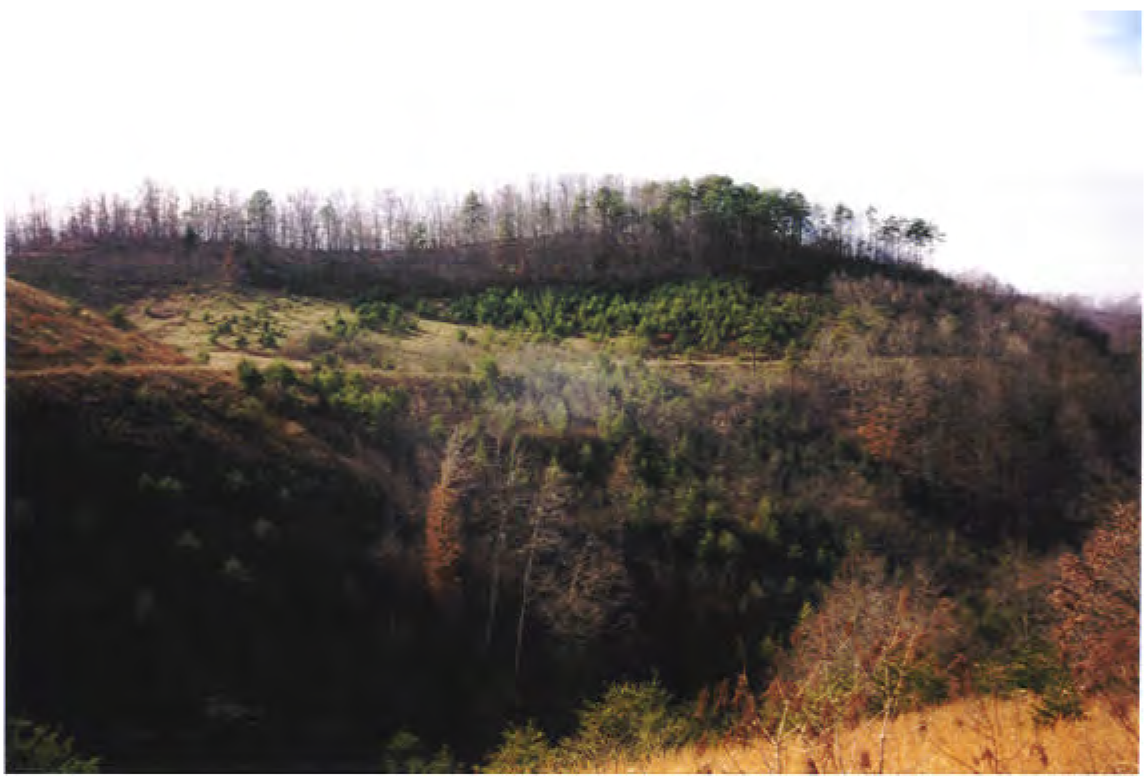
Groin ditches convey storm flow down face of valley fill

Groin ditch from upper sedimentation pond.
Photo shows outfall pipes from pond and early evolution of
"natural" channel within ditch.

Groin ditch into first of lower sedimentation ponds in series

Relocated reach of Rollem Fork.

Photo shows undisturbed forested hillslope to left and floodplain fill to right.



Reforestation of old valley fill along Frank's Branch.

Reforestation of old valley fill.
Groin ditch barely visible in center of photo.

4. Arch Coal Company
Hobet # 21 Mine

a. General

This mine is located near the town of Madison, West Virginia. The operations at this site consist of ridgetop surface mining utilizing walking dragline and electric shovel methods. The streams draining the site include first and second order tributaries to Little Coal River and Mud River which are part of the Guyandotte River Creek drainage system. Approximately 30 -35% of the overburden material removed will be disposed of in valley fills. The valley fills are composed of durable rock fill built in 50 to 100 foot lifts.

Stormwater runoff conveyance and sediment control are provided for via a network of combination ditches, groin ditches, and sedimentation ponds. This network is designed to convey all storm flows up to and including the 100-year runoff event and sediment that is eroded and transported from exposed surfaces. The combination ditches collect and convey stormwater flow around the perimeter of the valley fill. Although the dimensions of the ditches vary with drainage area, they are commonly constructed with 10 - 15 foot bottom widths and 6 – 8 foot depth. They have a relatively flat gradient and stone weirs are spaced regularly along the ditches to improve sedimentation rates. The ditches are stabilized with a grass mix. Groin ditches convey stormwater flow down the face of the valley fill. They are usually 10 – 15 feet wide. Although breaks in slope occur at the benches where the perimeter ditches contribute their flow, the groin ditches are generally very steep. Groin ditches are lined with large rock to provide stabilization. Sedimentation ponds are constructed at points along the combination ditches on top of the valley fill. Although the tour did not include the base of the valley fill presumably ponds have been constructed there as well. This system serves to convey storm runoff and capture and retain sediment transported off the exposed valley fill or active mining areas. The ponds are sized to manage the entire disturbed area. . Some of the ditches intercept groundwater at the back edge of the cut along the down dip side of the valley fill and therefore carry a baseflow. Where this baseflow discharges into the sedimentation ponds they retain a permanent pool. In other areas baseflow from the streams buried beneath the valley fill discharges into the ponds providing a permanent pool.

e. Evaluation of Current Practices

1. Watershed/Valley Characteristics

Operations on this site involve surface mining of ridgetops. Consequently, the amount of valley fill and disturbance to ridgelines is significant. The pre-mining difference in elevational relief from the ridgelines to the valley floors was fairly significant. Removal of ridgetops and disposal of overburden in valley fill has significantly reduced the elevational difference between the original ridgelines and valley floors. Contour/landform grading and backstacking of overburden to heights of 100 feet has restored some of the relief and natural landform.

Although the overall valley slope of the watershed was greater than 10%, pre-mining the down-valley profile included areas of varying slopes. Some valley reaches were very steep, while other reaches had a fairly gentle slope. In the valley fill areas, current reclamation practices have created a down valley slope that is uniformly moderate along the top of the fill and uniformly steep down the face of the fill.

The pre-mining cross-section of the valley also exhibited variability. Hillslopes were characterized by natural breaks where the form and gradient of the slopes changed from steep and convex to relatively gentle and concave and back to steep and convex. Reclamation has restored some of the valley cross-section along the ridgelines. Although the valley floor sits much higher in elevation, in some areas there has been an obvious effort to recreate the swale and meander associated with a naturally formed valley floor. The oldest area observed was reclaimed in the early 1980's. Reclamation of this area involved 250 feet of conventional fill with four-foot lifts and a chimney core drain down the center of the valley fill. In this area the valley fill is predominantly linear with a uniform slope.

2. Vegetative Cover

On this site all vegetation was cleared and grubbed prior to the mining operation commencing. Reclaimed areas were seeded with a grass mix. A few areas have been densely planted with one or two species of shrubs and trees.

The new valley floor in the older (1980's) reclamation area is predominantly grasses with scattered shrubs and trees and the adjacent slopes have a fairly good cover of trees. However, the revegetation effort on these slopes has resulted in an even-aged stand that lacks the species diversity and multi-layered vertical structure of a natural forest.

Most of the stabilized areas on site are covered with grasses and a few widely scattered volunteer shrubs. The remnant forests on site were isolated on undisturbed hillslopes adjacent to downstream reaches and unmined ridgelines.

3. Soil Characteristics

The valley fill is a durable rock fill laid down in lifts. The native topsoil and subsoil layers were removed as part of the mining operation. They were not separated and stockpiled for reuse during reclamation. The material laid down during reclamation is a coarse mixture of rock and other overburden material (e.g., sandstone, limestone, clay, shale, subsoils). This valley fill material has a very high percentage of mineral soil and very low percentage of organic matter. This material makes a very poor growth medium for reestablishing a forest. No information was available regarding permeability or infiltration rates of the valley fill material. However, since this unconsolidated material is composed of varying types of rock and soil it is likely that some areas will be permeable and other areas will be impermeable. Another factor affecting the permeability of the fill material is mechanical compaction of the fill surface by heavy equipment.

4. Hydrologic Regime

Some of the combination ditches intercept groundwater at the back edge of the cut along the down dip side of the valley fill and therefore carry a baseflow. These ditches support wetland vegetation. The baseflows are also maintaining a permanent pool in all the sedimentation ponds observed. Many of the ponds exhibited a dense growth of wetland vegetation around their margins. Although no data was available relative to the volume and time of concentration of storm flows, based on the characteristics of the fill material, compaction of the fill surface, and a relatively sparse vegetative cover, it is likely that the volume of runoff is significantly greater than under pre-mining conditions. It is also likely that the time of concentration for these flow events has been reduced with the potential to effect downstream reaches. The combination ditch/groin ditch/sedimentation pond systems help detain runoff and may provide some management of the increased storm flows.

5. Sediment Regime

No data was available to allow a quantitative comparison of erosion and sediment transport rates. However, it is likely that erosion and sediment transport rates from upland sources (i.e., active mining areas, valley fill areas, and adjacent disturbed areas) are significantly higher than pre-mining conditions. However, it appears that disturbed areas routed to the combination ditch/groin ditch/sedimentation pond systems are being managed effectively thereby limiting actual sediment loadings to the receiving streams. Erosion of the stream bed and banks in areas that adjust to accommodate the increased storm flow volumes may provide one unmanaged source of sediment to downstream reaches.

6. Channel Morphology

No information was available to determine the linear feet of first and second order streams permanently impacted by the valley fills. However, given the size of the fill areas observed during the tour the total stream length impacted is probably fairly substantial (i.e., several miles).

The morphology of the combination ditches and groin ditches are consistent with that of engineered drainage-ways, not natural stream channels. The combination ditches are wide, trapezoidal, and relatively flat. The groin ditches are also trapezoidal but very steep. There are no discernible bed features (i.e., riffle-pools) in the combination ditches. Since the channels are designed to convey runoff from larger storm events all flows are confined to that one channel. They were not designed to have a baseflow and bankfull channel with and adjacent floodplain. It should be noted that the constructed channels appeared to be stable and functioning as designed.

During the tour a combination channel in the Stanley Fork drainage basin was observed. This channel was constructed along the edge of a cut-slope and valley fill on the down dip side of the valley. Completed in 1995, it carries a baseflow and supports wetland vegetation. This drainage system also includes a series of shallow ponds and wetlands. The constructed channel is routed away from the face of the valley fill outfalling instead down an undisturbed forested hillslope. The result of this design has been to initiate the carving of a channel down a slope where none had previously existed. At the time of the tour it was evident that this channel is in its early evolutionary stages and would be characterized as a gully or G stream type (Rosgen, 1994). Although, the upper 200 feet of this reach is relatively stable, the lower sections are very unstable. Scour and degradation of the channel bed is proceeding in a downslope direction as a result of concentrated flows directed over these extremely steep slopes. In addition, a significant headcut was observed eroding upslope. This channel will continue to adjust for some time to come. Eventually it may erode to bedrock. This condition and/or the accumulation of large woody debris (LWD) will arrest the bed degradation and provide vertical control. Lateral adjustment will continue until the channel has carved the dimensions necessary to convey the bankfull and greater storm flows. Until this channel has reached a state of equilibrium it will be a significant source of sediment to downstream reaches. It is not known if this channel represents a common situation on this or other mining sites.

7. Physicochemical Properties

Although no receiving stream water quality data was available for this site, Maggard and Kirk (1998) monitoring streams draining other mountaintop mining/valley fill sites found that several water quality parameters had varied from pre-mining levels. Their data indicates that conductivity, total dissolved solids, hardness, alkalinity, sulfates, sodium, calcium, and magnesium had increased significantly. These trends in water quality may apply to the receiving streams on this site as well.

R.E.I. Consultants, Inc. (1999) evaluated the water quality of combination ditches and sedimentation ponds constructed on other similar mining sites. Water quality varied considerably between their sampling sites. For example, pH ranged from 5.04 - 8.77 in the ponds and from 5.32 – 9.39 in the combination ditches. They found that most of the chemical values (e.g., dissolved solids, hardness, alkalinity, sulfates, and most metals) were high. They found that water quality improved with the age of the structure. Their findings may apply to the water quality of the combination ditches and ponds on this site.

8. Biotic Communities, Trophic Structure, and Energy Sources

Although no receiving stream biological data was available for this site, Maggard and Kirk (1998) found that the benthic macroinvertebrate community downstream of mining/valley fill operations shifted toward more pollution tolerant species. Their data indicates that the number of individuals and taxa richness increased, while diversity and evenness decreased. These findings may apply to the tributaries of Little Coal River and Mud River downstream of this site.

R.E.I. Consultants, Inc. (1999) evaluated the biological communities in the combination ditches and sedimentation ponds constructed on other mining sites. The biotic communities that have developed in the combination ditches and sedimentation ponds include species typical of a lentic ecosystem. Macrophytes and filamentous algae provide primary production.

The benthic macroinvertebrate community is composed of typical pond species (e.g., Diptera, Coleoptera, Hemiptera, Odonata, and Oligochaeta. The communities in the newer facilities exhibited low abundance and diversity, and were represented predominantly by very pollution tolerant species. The older facilities, where water quality was better and vegetation was abundant, exhibited higher abundance and diversity. Species present were still primarily pollution tolerant organisms. The fish community was not represented in the ditches and ponds. In the short-term, it is unlikely that these structures will provide habitat for amphibians since most amphibian species are very sensitive to poor water quality.

Reclaimed area (1990).
Photo shows restored ridgelines, ponds, wetlands, and reforestation.

Recently reclaimed area with restored ridgelines and wetland system on valley fill

Face of recent valley fill

Combination ditch with baseflow

Combination ditch with baseflow. Photo shows wetland vegetation along margins of ditch.

Outfall of combination ditch routed over undisturbed forested hillslope

Gully erosion on forested hillslope. Headcut eroding in an upslope direction.

Summary of Findings

The results of this assessment indicate that current mining and reclamation practices result in significant adverse impacts to the first and second order stream ecosystems on mountaintop mining/valley fill sites. At all four sites evaluated watershed and stream characteristics have been significantly, and in most cases, permanently altered.

The shape, slope, size and aspect of the watersheds and valleys have been altered. Removal of ridgetops and raising of valley floors by disposal of overburden in valley fills have significantly reduced the pre-mining difference in elevational relief between the ridgelines and valley floors. The natural variability characteristic of valley profiles and cross-sections has been replaced with linear landforms and uniform slopes. Reclamation has reduced the size of the drainage area for some sites and enlarged it for others. Drainage patterns have been altered from the characteristic dendritic pattern to one best described as a modified trellis. Although the watersheds have no common aspect or orientation, for some reclaimed sites their original aspect has been modified.

Some sites have incorporated contour/landform grading and backstacking of overburden into their reclamation operations. The results of these efforts were obvious in restored elevational relief and more natural ridgelines. However, the watersheds and valleys are still very different than under pre-mining conditions. Some, perhaps all of these differences have the potential to modify the influence of prevailing winds, precipitation, and insolation on the hydrologic regime, soil characteristics, vegetative communities, and channel morphology which, in turn, effect the physical, chemical and biological characteristics of the stream ecosystem.

The creation of steep uniform slopes, disruption of the native soil and geologic strata by the mining operations, construction of fill surfaces with highly variable permeability, compaction of soils by heavy equipment, and alteration from forest to grassland all serve to modify the hydrologic regime of the sites. The result of these modifications is increased storm flow volumes and decreased time of concentration relative to pre-mining forested conditions. Although, the combination ditch/groin ditch/sedimentation pond systems are designed to convey storm runoff, it is unclear how effective these systems are at actually managing the increased flows and restoring the pre-mining hydrology.

In addition to the effects on hydrology mentioned above, the alterations in soil characteristics make the sites poorly suited for reestablishing forest cover. The soils are very sterile, that is, high in mineral content and low in organic matter content. The unconsolidated nature of the fills results in some areas with extremely high permeability rates typified by droughty soil conditions while other areas that have relatively low permeability rates typified by perched water conditions. Neither situation is conducive to reestablishing a natural forest. Soil conditions will naturally improve with time. However, until suitable soil characteristics redevelop the vegetative cover will be limited to grasses and scattered shrubs. The situation is exacerbated by the lack of potential seed banks adjacent to reclaimed areas on many sites. This situation is due to the complete removal or isolation of mature forests from the reclamation sites. Sites where forested ridgelines or hillslopes are adjacent to reclaimed areas may provide a source of pioneer species. However, without substantial changes to current practices reestablishing natural forest conditions on most of these sites could take as long as 400-500 years (S. Handel, personal communication).

Erosion and sediment transport rates from upland sources (i.e., active mining areas, valley fill areas, and adjacent disturbed areas) are probably much higher than under pre-mining conditions. The combination ditch/groin ditch/sedimentation pond systems are being managed effectively and limit the actual sediment loadings to the receiving streams. However, erosion of the streambed and banks in areas that adjust to accommodate the increased storm flow volumes provide a potential unmanaged source of sediment to downstream reaches. Two specific problem areas were pointed out in the *Assessment Results* section. The first area involved an entrenched runoff ditch that was experiencing headcut erosion at the break in slope where the channel gradient suddenly increased. The second site involved a combination ditch that had been routed away from the face of the valley fill outfalling down an undisturbed forested hillslope. The results of this situation were even more severe. Scour and degradation of the channel bed is proceeding in a downslope direction and a significant headcut is eroding upslope. Until these channels have been stabilized or naturally evolve to a state of equilibrium they will be significant sources of sediment to downstream reaches. It is not known if these cases represent common situations on surface mining sites.

If the size of the valley fill areas observed during the tour is representative of mountaintop mining/valley fill operations, the total stream length of first and second order streams that could be impacted by current and future surface mining operations is substantial. Utilizing information from these sites it is estimated that approximately 10 linear feet of stream channel are directly and permanently impacted (i.e., buried beneath valley fills) for each acre of surface mining. An additional 3 feet of stream channel are directly and temporarily impacted (i.e., construction of on-line sedimentation ponds) for each acre of surface mining. This equates to 12,000 linear feet (2.27 miles) of permanent impacts and 3600 linear feet (0.68 miles) of temporary impacts or a total of 15,600 linear feet (2.95 miles) of impacts on a 1200-acre surface mining site. These numbers raise two critical questions. Can these impacts be avoided? How can unavoidable impacts be minimized and/or mitigated?

Consideration is being given to mitigating for the adverse impacts to the natural channels on surface mining sites by creating aquatic habitat in the drainage systems (i.e., ditches and ponds) routinely constructed to convey runoff and control sediment eroded from the disturbed areas on site. On a linear foot basis this should be feasible since an equivalent number of miles (or greater) of channel are created in the combination and groin ditches.

The critical issue is whether the constructed drainage systems can mitigate for the impacts to the natural stream ecosystems on the surface mining sites. The results of this assessment provide insight on this issue.

The morphology of the combination ditches and groin ditches are consistent with that of engineered drainage-ways, not natural stream channels. The combination ditches are wide, trapezoidal, and relatively flat. The groin ditches are also trapezoidal but very steep. There are no discernible bed features (i.e., riffle-pools, step-pools) in the ditches. These ditches were designed to convey runoff from larger storm events with all flows confined to one channel. They were not designed to have a baseflow and bankfull channel and an adjacent floodprone area.

Most of the drainage systems observed during the tour carry storm flow only (i.e., during and immediately following storm events). Only a few sites were observed where these ditches and ponds had been constructed along the edge of a cut-slope and valley fill on the down dip side of the valley. These ditches and ponds do carry a baseflow. Most of these drainage systems support wetland vegetation. The more complex systems include combination ditches and a series of shallow ponds and wetlands.

Although biotic communities have developed in many of the ditches and ponds the species present are typical of lentic ecosystems. Abundance and diversity are low and most species are very pollution tolerant. The structure of the biotic community is in part due to channel morphology (wide, shallow and low gradient) and flow conditions (i.e., slow moving or standing/ponded water). It is also influenced by poor water quality and a lack of vegetation.

Woody vegetation in the riparian zone is sparse or non-existent. No obvious attempts have been made to plant trees or shrubs in these areas. Consequently, macrophytes and filamentous algae provide primary production in these systems.

The results of this assessment indicate that first and second order stream ecosystems are being significantly impacted by mountaintop mining/valley fill operations. Current mining and reclamation practices have not been effective at avoiding or minimizing adverse impacts to these stream ecosystems and aquatic habitat enhancement in the constructed drainage systems does not mitigate (i.e., replace) the natural structure and function of the first and second order stream ecosystems that existed pre-mining. .

Summary of Recommendations

This section focuses on recommended approaches for minimizing and mitigating unavoidable adverse impacts to first and second order stream ecosystems on mountaintop mining/valley fill sites.

1. Modifications to Overburden Disposal and Reclamation Practices

Current mountaintop mining/valley fill practices involve the removal of overburden from ridgetops to expose the coal seam(s) for mining. The overburden removed is disposed of in the adjacent stream valleys. Valley fill is usually laid down in 50 to 100 foot lifts. The new valley floor (i.e., top of valley fill) may be 400-600 feet above the original valley floor. Generally, lifts are constructed such that the face of successively higher lifts is set back 25-40 feet from the lift immediately below it. This creates a bench of uniform width across the valley fill. Removal of ridgetops and disposal of overburden in valley fill significantly reduces the elevational difference between the original ridgelines and valley floors. In the valley fill areas, current reclamation practices create a down valley slope that is uniformly moderate along the top of the fill and uniformly steep down the face of the fill. The reconstructed landform is predominantly linear and uniform on most sites.

Landform grading and backstacking of overburden to heights of 200 –300 feet would restore some of the relief and natural landform of the ridgelines. The backstacking to higher elevations would also provide additional upland disposal areas thereby reducing the volume of overburden placed in valley fills. Although millions of cubic yards of overburden material are removed during the mining operation, regulation requires that the bulk (80%) of the material segregated for disposal as valley fill must have been determined to be durable and geochemically suitable. A portion of the overburden removed will be unsuitable for valley fill disposal. It would seem that these requirements would encourage the disposal of overburden material in upland areas as opposed to the valley fills.

Landform grading and modifying construction practices for the fill lifts could restore the natural form and slope of the valleys. This would involve constructing irregular lifts of varying face height and bench width. For example, a series of 15-foot high lifts with 10 foot wide benches might be followed by a series of 5 foot high lifts with 50 foot wide benches. Lifts could be constructed such that those along the margins of the fill at the interface with the hillslopes extend further out while those toward the center of the valley fill are inset. The left side of a lift could be constructed higher than the right side to provide variable cross-valley slopes.

Utilizing this approach, valleys could be recreated with a down-valley profile that includes areas of varying slopes. Some valley reaches would be very steep, while other reaches would have moderate or even fairly gentle slope. The variability exhibited by the pre-mining valley cross-section could be restored creating ridgelines and hillslopes with natural breaks where the form and gradient of the slopes change from steep and convex to gentle and concave and back to steep and convex. Although the valley floor would still sit much higher in elevation, the swale and meander associated with a naturally formed valley floor could be recreated.

The characteristics of the fill material itself should be modified. The upper layers must be amended to provide a growth medium suitable for reestablishing a natural forest. This could be accomplished by working in stages. The first stage would involve laying down a layer of mulch and topsoil. The mulch can be prepared from the vegetation cleared and grubbed from a new surface mining site. The topsoil can be salvaged from that same surface mining site as well. After the soil has been prepared it is fertilized and seeded with a grass mix of rye and clovers and native meadow grasses.

To initiate the process of reestablishing a natural forest, a variety of native of tree and shrub pioneering species should be planted on the newly reconstructed ridgelines and hillslopes and along the valley floors, concentrating on the drainage ways. This vegetative community should be established (10-15 years) prior to the introduction of native tree and shrub forest species. Where reclaimed areas are adjacent to undisturbed forests this successional process may be accelerated.

2. Restoration of stream channels and floodplains

Opportunities for restoration of existing streams were harder to identify where ridgetop mining operations were predominant and valley fills had been extensive. For example, removal of on-line ponds from all the tributaries to Mudlick and Stollings Creek at Elk Run's East of Stollings Mine site would recapture approximately 1800 linear feet of stream channel with the two longest individual reaches being less than 500 feet each and the rest ranging from 100 – 250 linear feet. However, on sites where contour mining was predominant and valley fills had not been as extensive a number of restoration opportunities exist. For example, removal of on-line sedimentation ponds, floodplain fill, and sections of access road from Rollem Fork at Pen Coal's Kiah Creek Mine site would recapture approximately 3600 feet of stream channel.

Rollem Fork provides an excellent example for presenting recommendations for restoration of stream channels and floodplains. Rollem Fork appears to have been relocated at some time in the past. Floodplain fill resulting from construction of the pond berms, disposal of sediment removed from the ponds, and construction of the access road has confined the stream between the fill and the adjacent hillslope. This condition has created an entrenched G stream type channel. Woody riparian vegetation is sparse along the fill side of the channel. One restoration approach would involve lowering of the pond berms, and removal of floodplain fill and sections of access road. The existing stream channel should be relocated away from the hillslope and towards the center of the valley floor. This would also provide a floodprone area to accommodate overbank flows. The off-line ponds at the base of valley fill and in the floodplain could be combined and reconstructed as one large freshwater marsh with varying hydrologic regimes (i.e., permanently flooded, seasonally flooded and seasonally saturated). The outfall pipes should be removed. The new outfall to this freshwater marsh/pond would be a small E stream type channel that meanders along the floodplain before emptying into Rollem Fork. The margins and seasonally saturated areas could be planted with trees and shrubs and the flooded areas with emergent vegetation. The riparian zone along both banks of the stream should be heavily planted with native trees and shrubs.

3. Modifications to design of combination ditch/groin ditch/sedimentation ponds

Many of the combination ditches and groin ditches observed convey storm flows only. Most of them appeared to be stable and functioning as designed. Unless baseflow can be diverted to these channels, there is no reason to modify them. Where opportunities exist to capture groundwater and generate a baseflow, the channels should be constructed with natural channel morphology including planform, profile, and cross-sectional geometry. Vertical and horizontal controls and flow diverting structures should be installed to stabilize the channel bed and banks.

The design of these natural channels would include baseflow and bankfull channels and floodprone areas. The channel form should be consistent with that appropriate for the valley type in which they will be constructed. For example, the steeper reaches (i.e., down the face of the fill) of a groin ditch redesigned as a natural stream channel would have the characteristics of an A or Aa+ stream type with a step-pool morphology. The lower gradient reaches (i.e., across the top of the bench) of groin ditches and most combination ditches redesigned as a natural channel would have the characteristics of B, C or E stream types. Selection of the appropriate stream type would be guided by the characteristics of stream types and valley types presented in A Classification of Natural Rivers (Rosgen, 1994) and Applied River Morphology (Rosgen, 1996).

Specific design parameters would be developed utilizing a Natural Channel Design Approach that includes: the use of regional hydrologic and hydraulic geometry curves; channel morphology data obtained from field surveys of stable reference reaches of the same stream type as that determined to be appropriate for the particular on-site situation; vertical bed control provided by boulder and log drop structures, rock sills, cross vanes, etc.; horizontal bank control provided by toe boulders, soil fabric lifts, and dense growth of trees and shrubs along the banks and in the adjacent riparian zone. Flow diverting structures (e.g., rock vanes j-hook vanes, cross vanes, w-weirs, etc.) can take stress off the banks by diverting flows toward the center of the channel. The vertical and horizontal controls and flow diverting structures are installed and key points along the channel. They stabilize the channel bed and banks as well as create and maintain diversity of channel features and habitat. Sedimentation ponds can be redesigned to create shallow marsh and open water habitats in the floodprone areas adjacent to the lower gradient channels (i.e., C and E stream types). Plantings of submerged aquatic, emergent, and woody vegetation would improve water quality and enhance the habitat for benthic macroinvertebrates, amphibians, reptiles and waterfowl. The natural channel design approach has the greatest chance for success if it also incorporates the modifications to valley fill practices presented above.

FURTHER AMPLIFICATION AND CLARIFICATION OF ISSUES RELATING TO LANDFORM RESTORATION
by
HORST J. SCHOR

The impact on aquatic habitat and the elimination of streams through the valley fill process is really secondary and only provided the legal "hook" to those opposed to current practices of Mountain Top Removal/Valley Fills. It has been my observation that the primary and more fundamental issue is, what is perceived by a large segment of the public as the destruction, the "flattening out" of an existing, pristine, mountainous topography with the concurrent loss of the entire biological habitat on a fairly significant scale.
Current reclamation practices do not typically:

?? restore a natural topography – mountain tops and valleys and the associated topographic relief
?? restore a natural hydrologic system, they only "control" drainage
?? restore streams but, build engineered ditches
?? re-vegetate the reclaimed forms to their original or approximate original condition; distribution of trees, shrubs and ground cover species is not done by aspect or by elevation but, rather uniform and standardized; single groundcover mix is optimized for quick germination, dense coverage and erosions prevention often preventing success of other plant and tree species

All of the above objectionable practices can be mitigated if the industry and its regulatory agencies are willing, and some issues have already been addressed by some companies. Reclamation efforts at the Sample and Holbert Mines demonstrated that the industry is capable of restoring the mountaintop component of the original landforms and they need to be commended for their efforts.

Not only does it recapture an aesthetic element of West Virginia's topography, it is also reported to be more cost effective than conventional practices in drag line operations. It further controls erosion on constructed fill slopes without unsightly, traditional benching techniques by breaking the man made topography into smaller, none-erosive tributary drainage areas - just like in nature.

In terms of landform restoration, we are half-way there!

However, the element, even with their efforts, that is still missing, is the recreation of the valley form. Some of their spoil fills (parts of the recreated ridge tops) are actually stacked on top of valley fills. Valley fills need to be significantly depressed so that there can be a more gradual transition of the valley floor downstream from the fill segment to the undisturbed natural valley/stream. Mountain top fill heights are then increased to make up for loss of the valley's holding capacity.

Valleys are the foundation for streams. They are the collectors of both surface and subsurface drainage, they capture, hold, concentrate and channel the water and together with the topography and vegetative cover become part of the overall aesthetic natural landscape of any mountainous terrain.

You can't have streams without valleys forms, you can only build drainage ditches or, as Dr. Handel put it so well, build plumbing devices.

I believe that the loss of the valley form with its associated stream habitat through the filling process, appears to be the most serious and objectionable element in the public's perception. It is only through ways of restoring this landform component with its habitat that we can hope to find a middle ground to resolve the controversy, or valley fills may become highly restrictive, if not off limits entirely.

It would be unfortunate if, because of the inflexibility of the industry, a court's ruling would set reclamation practices rather than the technical expertise and the creative minds of the industry itself and the cooperation of regulatory agencies. It is recognized that this will require different design techniques, construction processes and maybe even machinery to achieve this objective but, that has been done before as this industry evolved from underground to surface operations.

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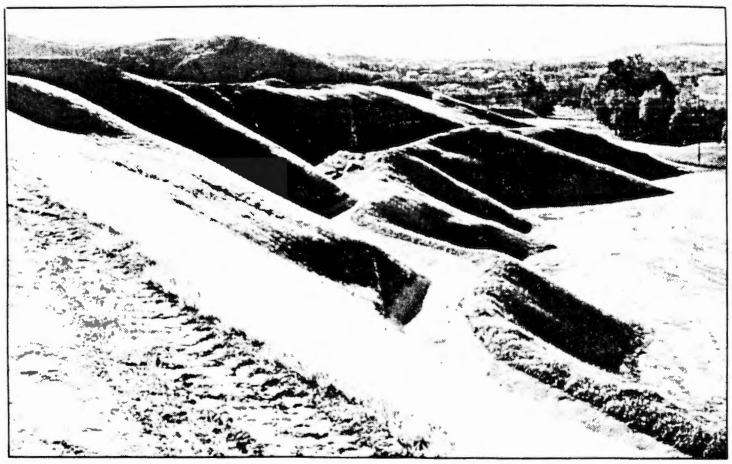

Landform grading sculpts the hillside of Talega project into new shapes in technique created by Horst Schor.

Grading on the Curve

Developer Goes for Natural Look in Sculpting Hills for Talega Project

By JOHN O'DELL
TIMES STAFF WRITER

SAN CLEMENTE

Fred Moeller has been operating bulldozers for almost 40 years now, piling dirt, cutting trenches and grading slopes all over Southern California.

But for all his experience, Moeller has never been on a job quite like this one.

Usually, when preparing hillsides and valleys for a housing project, Moeller and other heavy-equipment operators are asked to prepare a stairstep arrangement of flat-faced slopes with building pads on top.

At Arvida Co.'s Talega development in the hills just inland of Orange County's southernmost city, the rules have changed.

Moeller and fellow operators are being asked to think like sculptors as they follow a complex natural grading plan that calls for them to create slopes, valleys, gullies, hillocks and ridgelines for the homes and commercial buildings that will one day dot the 3,500-acre master-planned community.

In some places they are merely altering existing slopes to accommodate building pads. In others they are creating hills where none ever existed.

The grading process was invented in the late 1970s by Horst Schor, now Arvida's vice president for development. At the time, Schor worked for the Anaheim Hills Co. as it was developing its hillside community on the southern slopes of Santa Ana Canyon.

KEN HIVELY / Los Angeles Times

Fred Moeller guides his 25-ton bulldozer over a mound.

But no one else ever picked up on the idea, Schor said, despite the industry publicity the technique received at the time, when the American Planning Assn. bestowed an award of merit on Anaheim Hills Co. for its innovative natural grading plan.

One reason other developers didn't adopt what Schor calls landform grading is that it costs a little more—adding about 1% to a project's grading costs—and requires a little effort to train the grading crews.

"But Arvida feels the time is really ripe for this," he said. Environmental concerns and complaints about development that destroys natural landscape and ridgelines can delay projects for months, even years. Schor said Arvida's natural grading plan shaved at least 12 months off the time it took to get approval from San Clemente officials for the Talega development—which is located partly within the city and partly in unincorporated county territory. The time saved can more than make up for the extra grading costs.

There are three key elements of landform grading, he said Thursday during a demonstration of the process:

- Building hills and slopes with natural contours;
- Fitting the drainage system into the flow of the land so it follows the valley bottoms like a natural creek system instead of cutting straight down the face of slopes with concrete channels, as is done in a typical stair-step grading plan; and

Please see TALEGA, D7

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Grading on the Curve

Developer Goes for Natural Look in Sculpting Hills for Talega Project

[continued]

Continued from D6

• Designing a natural landscape plan that mimics nature by placing the trees and shrubs in the valleys and on flat spots, where the heaviest runoff collects, and covers the protruding areas with less-thirsty ground covers.

For Moeller, who spent Thursday morning contouring a small hill with a 25-ton Caterpillar bulldozer, the process isn't much more difficult than building a traditional stairstep.

"It's a lot more challenging, because you're not just going in straight lines."

Russ Churchill, who works with Moeller and the other equipment operators as a grade checker—overseeing their work from the ground to make sure they are following the grading plan—said there is a lot more for him to concentrate on in a landform grading project.

"It's challenging," said Churchill, "but it is very satisfying to see the end result. I didn't really see the whole thing we're working on here until the other day when I was leaving the site about 6 in the evening and I happened to look back up the road and saw it all highlighted with the setting sun and the shadows. It was really awesome."

GLENN KOENIG / Los Angeles Times

Traditional grading of sites for homes is shown in picture of Tuscany Hills development in Lake Elsinore area.

Landform Gradng Building Nature's Slopes

By HORST SCHOR
Senior Vice President, Anaheim Hills, Inc.

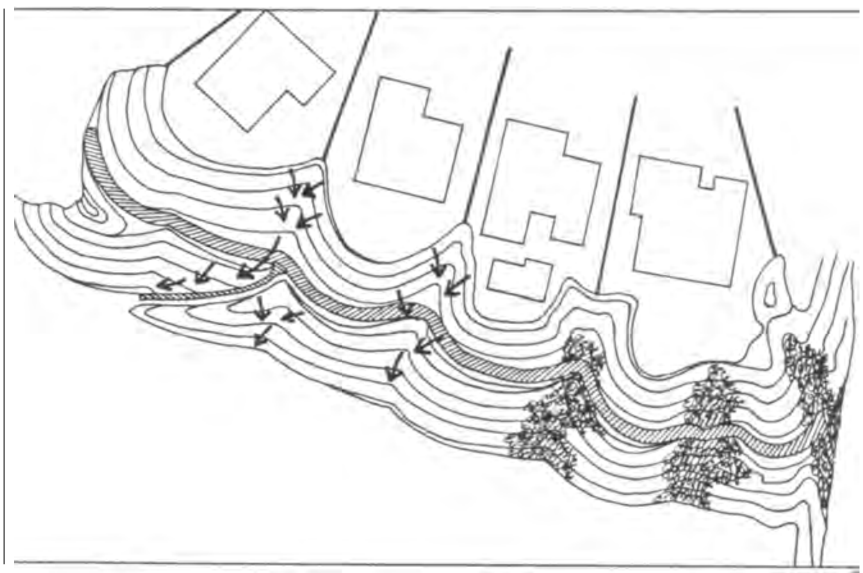
The advantages and necessities of hill-side living are becoming more widely evident as flatlands — the traditional building sites — are consumed by housing, industry and agribusiness.

However, hillside building can require massive grading that may become the focal point of local resistance, thus impeding planning approval. The innovative "landform" grading method was born of negative impressions gained in viewing the conventional, linear slopes commonly manufactured throughout the building industry.

Hills agreed to finance the experimentation and to use the results in the community.

There seemed to be no reason we couldn't grade the slopes to resemble natural slopes. The question then arose: what do natural slopes look like? Curiously, there was no published information about slope shapes as a total unit We were on our own.

Project research involved study of slopes in such diverse areas as Death Valley, Brazil, Alaska, Hawaii and Anaheim Hills in an attempt to separate dis-



TOPOGRAPHICAL *REPRESENTATION* of a section of landform-graded slope, showing radial water flow, foliage placement in swales and redistribution of land on lots to conform with landform configurations. Hatched area is concrete terrace drain required *by* building codes.

Anaheim Hills is situated in 4,300 acres of beautiful, undulating hillsides in northeastern Orange County, California. We, like every other developer, were taking natural terrain and transforming it into rigid, mathematical shapes for building. It was a practice based on the idea: "We've always done it that way." Since there was no specific reason, other than expediency, why it was being done, the time had come to examine ways of changing the accepted thinking about mass grading. The search for an alternative was an attempt to improve the aesthetics of graded hillsides. Anaheim

tinct features from among the natural slopes and to determine if there was any relationship between climate, soil type and vegetation and slope configuration. Yet it was two years before distinct, repeating patterns emeged from the jumble of forms. Simply stated, cones, pyramids, "elbows," ridges and various combinations of these elements produce natural slope shapes.

The challenge was now to apply these basic shapes to the grading process. Could they be designed and graded? We would have to retrain everyone concerned with the project. Designers, engineers, grading contractors and public officials had always worked in straight lines. Now we were saying, "the more irregular, the better."

Communication of the new ideas was difficult at times. Initially we made clay models in which we combined the basic slope shapes and took them out to the civil engineers and grading contractors. They, in turn, conveyed the ideas to their equipment operators in the field. However, the grading was not shaping up as we expected. We finally had to go into the field and call a bulldozer operator off his machine, show him the drawings and photos and explain the ideas. He then said, "Sure, I can do that. Why didn't you say that in the first place?" With each grading project, we improved and streamlined the operations.

We've now been doing the grading in Anaheim Hills for seven years. Contractors experienced in landform grading prefer it because the finished product doesn't need to meet precise slope-angle measurements, and it affords the operator more leeway in his bulldozing.

There is less finishing cost to the contractor, although there are more engineering, design and field control costs in landform grading. The cut and fill slopes are very complex to design. It is an art to assemble the various shapes on the slopes so they won't look unnatural. They have to blend together and work structurally. Landform grading gets its look not from one component shape or one gully but from a series of them. The landform shapes become a sequence of undulations, peaks and gulleys.

We have to deal with three planning commissions in Aanheim Hills: the cities of Anaheim and Orange and the County of Orange. The planners are delighted with the landform grading idea. At first they were doubtful, but once we'd graded several slopes, we invited them out for a look. Thev walked over the slopes, viewed them from different angles and saw the value of what we were doing.

The civil engineers were more skeptical. Thev felt that the shapes we were creatine would cause severe erosion. We proved them wrong. Earlv on, we graded an experimental slope 70 feet high without the artificial drainage interception aids required by the building codes. Rather, we let the curves and elbow shapes of the landforms absorb the impact of the running water, as happens in nature.

The rains from 1977 to this year have been heavy. From September through March 1977-78, it rained more than 31 inches. The same period in 1978-79 gave us more than 21 inches, and 1979-80 during the similar months put more than 22 inches of water on the slope. The slope is still in perfect condition. Nature doesn't follow building codes, but its designs still work.

Ironically, we found that conventional, angular grading tends to encourage erosion. Water generally will sheet flow on a flat surface and will tend to carve swales in the weakest sections of the slope. To compensate, building regulations require terrace drains every 25 feet to break the momentum of the water. Yet there is an entire set of building regulations predicated upon the efficiency of conventional, linear slopes.

On the other hand, the drainage pattern of a landform-graded slope is radial in nature and swales are already provided for the runoff. If the land is formed naturally, as in our process, the water follows the channels, which break its speed by virtue of their energy-dissipating shapes. Further, most foliage occurs in the channels or swales, and its presence breaks the speed of the running water. Our landscaping also follows this natural pattern. We also experimented with such ideas as planting Acacia Rosemary, a lush, low growth, to cushion the impact of rainfall.

Mother Nature is full of surprises. She knows how to control erosion without using the clumsy terrace drains we use in man-made slopes. We've minimized the visual impact of the required concrete drains by running them diagonally and curvilinearly across the slopes, which makes them considerably less visible. We also line them with river rock, so when they are visible they complement the landform slope aesthetics.

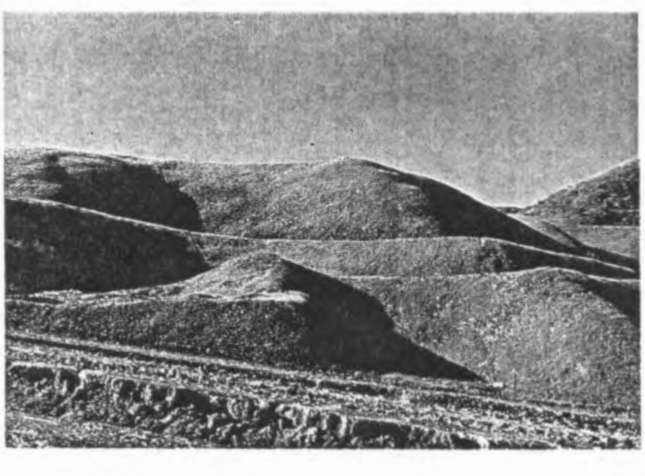
AERIAL PHOTO of landform-graded region in Anaheim Hills. Note irregular patterns formed by landform-graded slopes along perimeter of lot pads.

Initially, we and the builders were concerned about the buildable land that would be lost to the landform grading process on each lot. We solved that by reshaping backyards to conform with the grading configurations. The center sections of the lots, which are used most extensively, bulge outward with the ridgelines of the grading. The corners of the yard are taken up by the swales and these edges are characteristically used less often. In effect, we redistributed the lot pad square footage to our advantage.

We are pleased with the results of our experiments. When covered with mature vegetation, our landform graded slopes appear very much like natural slopes. The grading has allowed us to move away from straight lines and abrupt angles in our community planning. The homes are positioned more irregularly, which discourages the monotonous look of row housing. And, importantly, we come very close to restoring the slopes to their natural conditions.

We believe that sooner or later developers will be required to use this type of landform grading. This method of grading is part of the future of land development in this country and eventually in all other countries because most urban and suburban flatland has been built upon in one way or another. Landform grading involves more effort to achieve, design, implement, construct and engineer. However, the cost in time and labor is well worth the results of aesthetics, structural integrity and the value to developers of public acceptance and municipal planning approval.

FRESHLY GRADED landform slopes show ridges, swales and pyramid shapes.



MATURE LANDFORM slopes with vegetation and foliage in swales.

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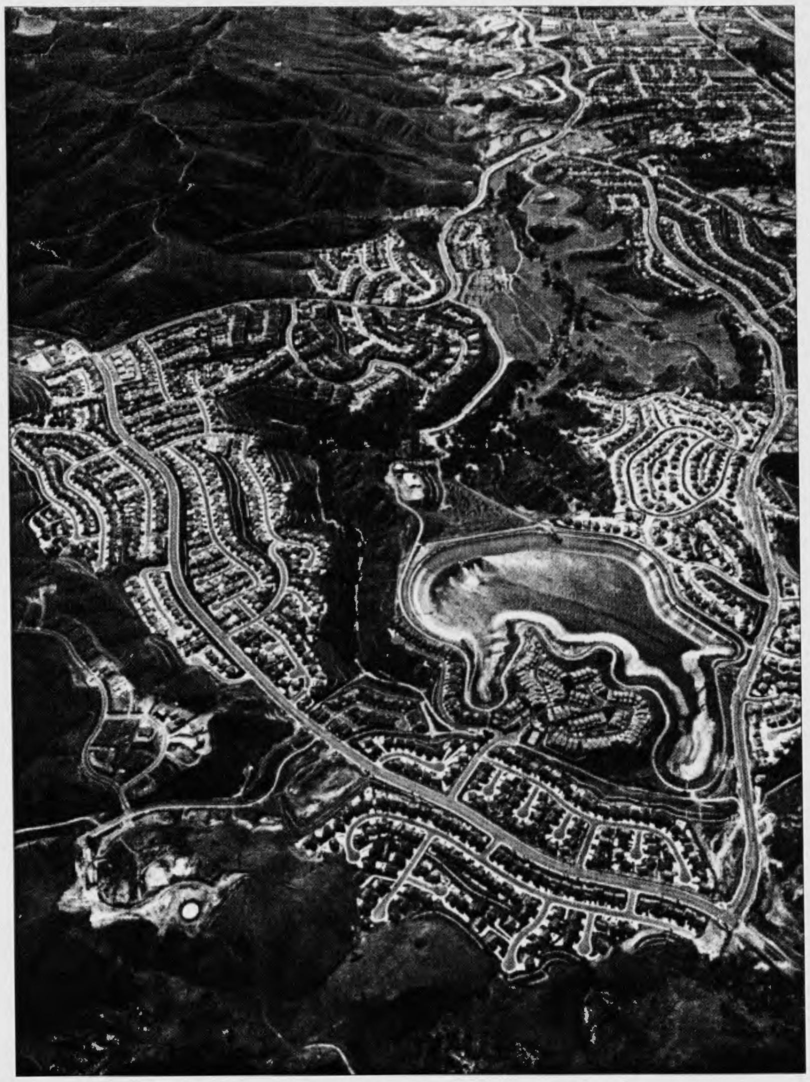
AND SPECIFIER NEWS



HILLSIDE DEVELOPMENT

See the LASN Marketplace on pages 26 - 41

Landform Grading:
Comparative Definitions of Grading Designs

by Horst J. fchor

The advantages and necessities of hillside living have becnme more widelv evident as flatlands, the traditional building sites, are being consumed rapidly by urban development.

Hillside building, while appealing to the consumer, can require massive grading that may become the focal point of local resistance, thus impending government approval.

However, grading is a necessity to accommodate street and building areas for development, meeting building codes, and safe engineering practices. Grading is also frequently required to correct unstable soils and geologic conditions inherent in many natural hillsides.

The innovative "Landform Grading and Revegetation" concept was conceived to solve negative impressions gained in viewing the typical re-manufactured hillsides using conventional planning, engineering and construction methods. Conventional grading drastically alters a landscape, remanufacturing natural forms and shapes and plant distribution patterns to replace them with artificial, sterile and uniform shapes and patterns.

The concept, as developed and described here, consists of three components:

- Grading
- Drainage Structures
- Revegetation/Landscaping

Grading

In recent years attempts have been made by some to design and construct "LANDFORM grading," while in reality, these efforts can only, at best, be described as contouring or rounding of slopes. Therefore it is necessary to establish proper definitions and characteristics for the three types of grading available: Conventional, Contour and Landform Grading.

Comparative Definitions of Grading Designs

Conventional Grading

- Conventional graded slopes are characterized by essentially linear, planar slope surfaces with unvarying gradients and angular slope intersections. The resultant pad configurations are rectangular.

- Slope drainage devices are usually constructrd in a rectilinear configuration in exposed positions.

- Landscaping is applied in random or geometric patterns.

Contour Grading

- Contour-graded slopes are basically similar to conventionally graded slopes except that: the slopes are curvilinear rather than linear, the gradients are unvarying and profiles are planar, transition zones and slope intersections have generally some rounding applied. Resultant pad configurations

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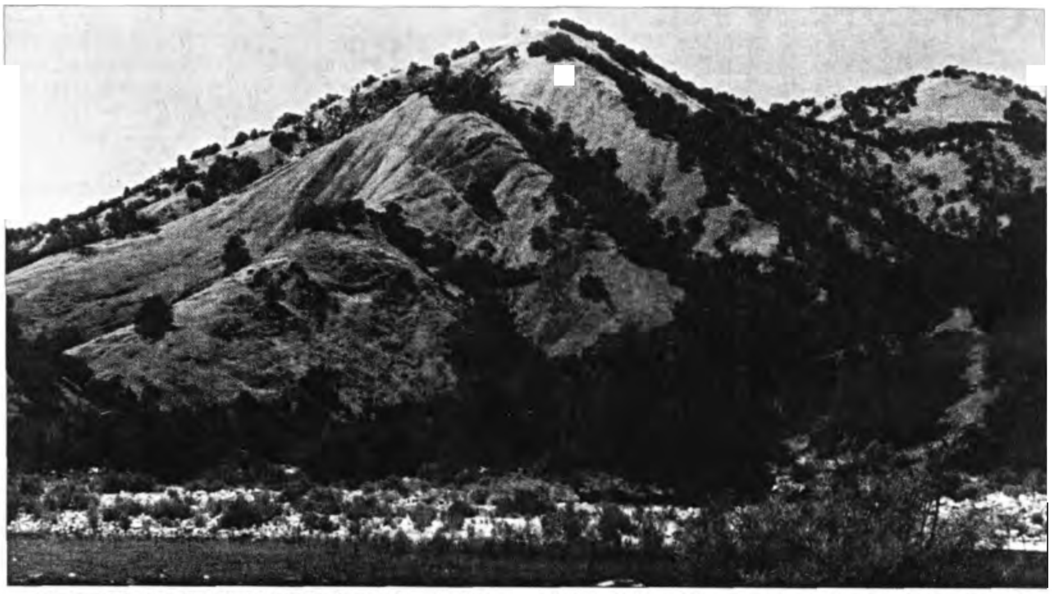

The natural hillside above illustrates that vegetation clusters in the swales of the mountain. The goal of landform revegetation is to replicate these natural patterns.

As opposed to the rigid forms of conventional grading (below left), landform grading (below right) provides shadows, depth and a more natural looking hillside.

Continued from page 23

while convex portions are planted mainly with ground covers.

Revegetation/Landscape

Historically, landscaping on manufactured slopes has been applied in uniform patterns, with trees typically spaced **15** feet on center and shrubs **3** feet on center to achieve what has been known in the industry dubiously as "Uniform Coverage."

It is this uniformity that can add to the artificial, man-made **look,** already created by the uniformity in grading.

In the "Landform Grading and Revegetation" approach, landscaping is applied in patterns that occur in nature.

The approach should be thought of as "Revegetation". Trees and shrubs require more moisture, so it makes sense to cluster them in the swales and valleys where moisture concentrates and evaporation is minimized. Shrubs are heavily concentrated along the drainage flow of each swale and thinned to each side to minimize any erosion.

The result of "Revegetation" is a landscape that does not **look** "man-made," and, where plant material locations and distributions serve a purpose and make sense.

"Revegetation" in combination with landform grading reduces irrigation's needs: radial drainage patterns that concentrate runoff in concave swales provide the most moisture to plant types that need the most. Flatter slope ratios in swales near the lower half of the slope slow water velocity and thus allow better absorption by plant roots.

Conclusion

Hillside development can be done in an aesthetically pleasing manner. Landform-grading and landform revegetation are just two concepts that accomplish this goal. With sensitivity, creativity and the will to improve, we can shape our hillsides by imitating mother nature to recreate a more "natural" habitat for all.

Horst Schor is the principal of H.J. Schor Consulting, Creative Concepts in Land Development, in Anaheim, California. **LASN**

The aerial photo to the left sham a *4.100* acre planned community In which the design revolves around the landform gmding and revegetation concept.

The hill above Illustrates how landform grading replicates the Irregular shapes of natural slopes. The landscaping will be a "revegetation process emulating the patterns of natural growth.

In high visibility arms. concrete drainage devices are lined with natural river rock to create a stream bed effect (right) in the finished landscape.

are mildly curvilinear.

• Slope drainage devices are usually constructed in a geometric configuration and in an exposed position the slope face.

• Landscaping is applied in random **or** geometric patterns.

landform Grading

• Landform Grading replicates the irregular shapes of natural slopes, resulting in aesthetically pleasing elevations and profiles. Landform-graded slopes are characterized by continuous series of concave and convex forms interspersed with mounds that blend into the profiles. Non-linearity and varying slope gradients are significant transition zones between man-made and natural slopes. Resultant pad configuration are irregular.

• Slope down-drain devices either follow "natural" lines of the slopes or are tucked away in special swale and berm combinations to conceal the drains from view. Exposed segments in high visibility areas are treated with natural rock *(see right photo).*

• Landscaping becomes a "revegetation" process and is applied in patterns that occur in nature. Trees and shrubs are concentrated largely in concave areas,

Continued on page 25

Supporting Information Supplied by Horst J. Schor:

Grading on the Curve

Landform Grading: Building Nature's Slopes

Landform Grading Comparative Definitions of Grading Design

Landform Grading and Slope Evolution

Further Amplification and Clarification of Issues Relating to Landform Restoration

LANDFORM GRADING AND SLOPE EVOLUTION

By Horst J. Schor[1] and Donald H. Gray,[2] Member, ASCE

ABSTRACT: Transportation corridors and residential developments in steep terrain both require that some grading be carried out to accommodate roadways and building sites. The manner in which this grading is planned and executed and the nature of the resulting topography or landforms that are created affect not only the visual or aesthetic impact of the development but also the long-term stability of the slopes and effectiveness of landscaping and revegetation efforts. Conventionally graded slopes can be characterized by essentially planar slope surfaces with constant gradients. Most slopes in nature, however, consist of complex landforms covered by vegetation that grows in patterns that are adjusted to hillside hydrogeology. Analysis of slope-evolution models reveals that a planar slope in many cases is not an equilibrium configuration. Landform-graded slopes on the other hand mimic stable natural slopes and are characterized by a variety of shapes, including convex and concave forms. Downslope drains either follow natural drop lines in the slope or are hidden from view in swale-and-berm combinations. Landscaping plants are placed in patterns that occur in nature as opposed to random or artificial configurations. The relatively small increase in the costs of engineering and design for landform grading are more than offset by improved visual and aesthetic impact, quicker regulatory approval, decreased hillside maintenance and sediment removal costs, and increased marketability and public acceptance.

INTRODUCTION

All slopes are subject to erosion and mass wasting. Various measures can be invoked to slow, if not completely prevent, this degradation. Biotechnical slope-protection methods, for example, have attracted increasing attention as a cost-effective and visually attractive means of stabilizing slopes. This approach has been used to stabilize and revegetate cut-and-fill slopes along highways as well as slopes in residential hillside developments. Kropp (1989) described the use of contour wattling in combination with subdrains to repair and stabilize a debris flow above a housing development in Pacifica, California. Gray and Sotir (1992) described the use of brush layering to stabilize a high, unstable cut slope along a highway in northern Massachusetts. Brush layering and other soil bioengineering measures have likewise been employed (Sotir and Gray 1989) to repair a failing fill embankment along a highway in North Carolina.

Transportation corridors and residential developments in steep terrain both require that some excavation and regrading be carried out to accommodate roadways and building sites. The manner in which this grading is planned and executed and the nature of the resulting topography or landforms that are created affect not only the visual or aesthetic impact of the development but also the stability of the slopes and effectiveness of landscaping and revegetation efforts.

Succinct descriptions and comparative definitions of grading designs are as follows.

Conventional Grading

Conventionally graded slopes are characterized by essentially linear (in plan), planar slope surfaces with unvarying gradients and angular slope intersections. Resultant pad configurations are rectangular.

Slope drainage devices are usually constructed in a rectilinear configuration in exposed positions.

Landscaping is applied in random or geometric patterns to produce "uniform coverage."

Contour Grading

Contour-graded slopes are basically similar to conventionally graded slopes except that the slopes are curvilinear (in plan) rather than linear, the gradients are unvarying, and profiles are planar. Transition zones and slope intersections generally have some rounding applied. Resultant pad configurations are mildly curvilinear.

Slope drainage devices are usually constructed in a geometric configuration and in an exposed position on the slope face.

Landscaping is applied in random or geometric patterns to produce "uniform coverage."

Landform Grading

Landform grading replicates irregular shapes of natural, stable slopes. Landform-graded slopes are characterized by a continuous series of concave and convex forms interspersed with swales and berms that blend into the profiles, nonlinearity in plan view, varying slope gradients, and significant transition zones between man-made and natural slopes. Resultant pad configurations are irregular.

Slope drainage devices either follow "natural" slope drop lines or are tucked away in special swale-and-berm combinations to conceal the drains from view. Exposed segments in high visibility areas are treated with natural rock.

Landscaping becomes a "revegetation" process and is applied in patterns that occur in nature: trees and shrubs are concentrated largely in concave areas, whereas drier convex portions are planted mainly with ground covers.

GRADING APPROACHES

Conventional

Conventional grading practice often results in drastically altered slopes and the replacement of natural hillside forms with artificial, sterile, and uniform shapes and patterns. Conventionally graded slopes can be characterized by essentially planar slope surfaces with constant gradients and angular intersections as shown in Fig. 1. Slope-drainage devices are usually constructed in a rectilinear and exposed fashion.

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[1]Prin., H.J. Schor Consulting, 626 N. Pioneer Dr., Anaheim, CA. 92805 (714) 778-3767.

[2]Prof., Dept. of Civ. & Envir. Engrg., Univ. of Michigan, Ann Arbor, MI 48109.

Note. Discussion open until March 1, 1996. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on September 14, 1994. This paper is part of the *Journal of Geotechnical Engineering*, Vol. 121, No. 10, October, 1995. ©ASCE, ISSN 0733-9410/95/0010-0729–0734/$2.00 + $.25 per page. Paper No. 9236.

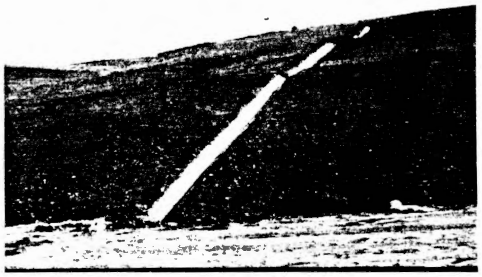

FIG. 1. Conventional Grading with Planar Slopes and Rectilinear Drainage Ditch in Highly Visible and Exposed Location

FIG. 2. Conventionally Graded Hill Slope with Planar Face, Rectilinear Drainage Ditch, and uniformly Spaced Plantings

Grading specifications in southern California, for example, typically call for flat, planar 2:1 ($H:V$) slopes with a midslope bench and a drainage ditch, commonly placed straight down the slope, that collects and conveys water from brow and midslope bench or terrace drains, respectively. Landscaping and plants are applied in random or geometric patterns as shown in Fig. 2.

Contour Grading

Contour grading offers a slight improvement over the sterile and simple geometry achieved by conventional grading. Some scalloping or curvilinear appearance is introduced onto the slope when seen in plan view; however, the slope gradients or profiles remain planar and unvarying. Transition zones at the bottom and top of slopes may also have some rounding applied. Slope drainage devices are still constructed in the same geometric configuration and exposed position on the slope face as in conventional grading. Landscaping and plants are also applied in random or geometric patterns.

Landform Grading

"Landform grading" essentially attempts to mimic nature's hills. This approach has been largely developed and pioneered by Schor (1980, 1992, 1993), who has successfully applied landform grading to several large hillside developments and planned communities in southern California. It is important to note that very few hillsides are found in nature with linear, planar faces. Instead, natural slopes consist of complex landforms covered by vegetation that grows in patterns that are adjusted to hillside hydrogeology, as shown in Figs. 3 and 4. Accordingly, landform-graded slopes are characterized by a variety of shapes including convex and concave forms interspersed with ridges and elbows in the slope.

Downslope drain devices either follow natural drop lines in the slope or are tucked away and hidden from view in special concave swale and convex berm combinations as shown in Fig. 5. Landscaping plants are not placed in random or artificial patterns. Instead they are applied in patterns that

FIG. 3. Natural Hill Slopes with Multiple and Complex Shapes and Profiles

FIG. 4. Natural Hill Slopes Showing Vegetation Patterns

FIG. 5. Example of Landform Grading with Drainageway that is Placed in Special Swale-and-Berm Combination to Conceal it from View

occur in nature (see Fig. 6). Trees and shrubs are concentrated primarily in concave areas, where drainage tends to concentrate, while drier convex portions are planted primarily with herbaceous ground covers. A schematic depiction of conventional site planning versus landform site planning is shown in Fig. 7.

SLOPE-EVOLUTION CONSIDERATIONS

Landform-graded slopes present more than a varied and pleasing visual appearance. They also tend to be intrinsically more stable. The general lack of straight, planar slopes in nature says something. Slopes wear away or degrade over time by gravity-driven forces of erosion and mass wasting. The slopes proceed toward an equilibrium profile, which evidently does not include a linear and unvarying gradient.

Geomorphologists have been interested for some time in various slope-evolution models. The spatial and temporal variation of any point in a slope can be expressed by a number of two-dimensional mathematical models. These models predict the rate of change of elevation (dY/dT) of any point on a slope with elapsed time (T) and coordinate location (X, Y). Examples of these mathematical models are the following:

$$\text{Model \#1 } dY/dT = -A \quad (1)$$

$$\text{Model \#2 } dY/dT = -B\,(dY/dX) \quad (2)$$

$$\text{Model \#3 } dY/dT = -C\,(\text{height above base}) \quad (3)$$

$$\text{Model \#4 } dY/dT = -D\,(\text{distance from crest})^{0.6} \quad (4)$$

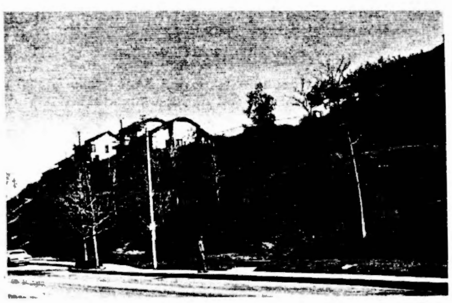

FIG. 6. Example of Landform Grading and Revegetation with Concave and Convex Slope Forms and Nonlinear, Varying Slope Gradients

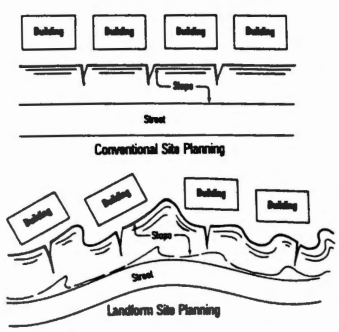

FIG. 7. Plan View of Conventional versus Landform Site Planning

$$\text{Model \#5 } dY/dT = -E\,(d^2Y/d^2X) \quad (5)$$

Graphical illustrations or simulations of these models are shown in Figs. 8–12. Each of these mathematical models has some physical basis. Model #2, for example, describes the "parallel retreat of slope" concept, which postulates that upon reaching its limiting slope angle (angle of repose) a slope retreats back at a constant inclination. A purely frictional, sandy slope whose stability is independent of slope height could conceivably fit this model. Model #4 fits observations from the Universal Soil Loss equation, which indicates that rainfall erosion losses from a slope (all other factors equal) are a function of the slope length. Model #5 is the so-called diffusion model, which postulates that in a transport-limited slope the passage of material down the slope from a point above is limited by the transfer rate at a point below. The slope profile adjusts itself over time to optimize this stepwise or sequential transfer of material downslope by various erosion or mass-wasting processes. Note that in the diffusion model, an initially planar slope evolves over time into a concave-convex slope as shown in Fig. 12.

The diffusion model (#5) was tested as part of a doctoral dissertation on slope evolution models at the University of

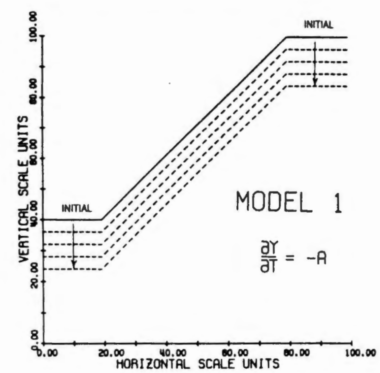

FIG. 8. Evolution of Hillside Slope when Rate of Lowering is Uniform over Entire Slope Profile (Model 1) [from Nash (1977)]

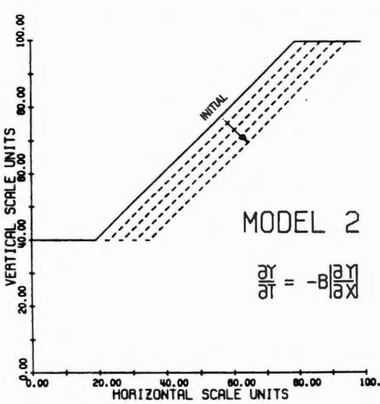

FIG. 9. Evolution of Hill Slope when Rate of Lowering at Point on Slope is Proportional to Profile Gradient at Point (Model 2) [from Nash (1977)]

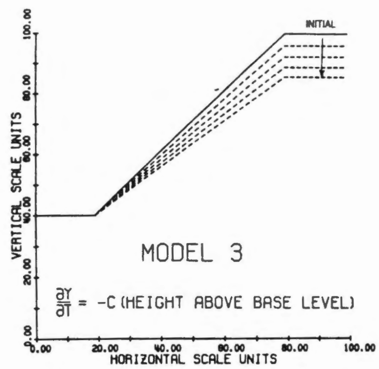

FIG. 10. Evolution of Hillside Slope when Rate of Lowering of a Point on Slope Is Proportional to Elevation of Point (Model 3) [from Nash (1977)]

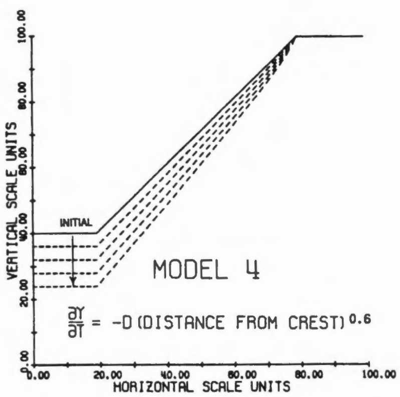

FIG. 11. Evolution of Hill Slope when Rate of Lowering at Point on Slope Profile Is Proportional to Distance that Point Lies from Crest or Divide (Model 4) [from Nash (1977)]

Michigan (Nash 1977). The slope profiles of present-day, modern wave-cut bluffs along Lake Michigan and those of ancient, abandoned bluffs marking former glacial lake margins were used for this purpose. The study assumed that slope processes at work on the bluffs have remained relatively constant over geologic time. The ancient bluffs and their ages respectively, are the Nipissing bluffs (4,000 yr) and Algonquin bluffs (10,500 yr). Actual slope profiles for these three bluffs superposed at their midpoint are shown in Fig. 13. The correspondence or fit between the profiles predicted by the diffusion model and the actual profiles was examined for various diffusion constants. The configurations predicted by the diffusion model for an abandoned bluff after 4,000 years and 10,500 years using a diffusion coefficient of 0.012 m^2/yr and an initial, planar profile similar to the profile of the modern bluff are shown in Fig. 14. According to the diffusion model, the slope profiles gradually change over time from a linear to a concave-convex configuration, as illustrated in Fig. 14.

The fit or correspondence between actual and predicted profiles is quite good as can be seen by comparing slope profiles in Figs. 13 and 14. More importantly, this modeling

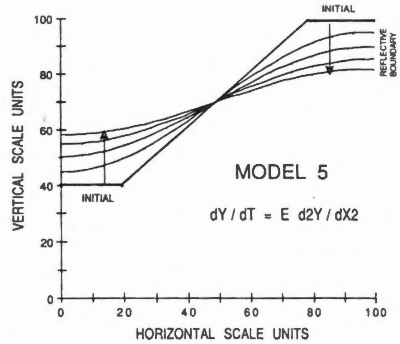

FIG. 12. Evolution of Hillside Slopes when Rate of Lowering of Point on Slope Profile Is Proportional to Profile Curvature at that Point, Assuming Reflective Left and Right Boundaries (Model 5) [from Nash (1977)]

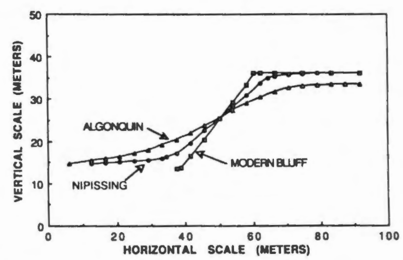

FIG. 13. Modern Bluff Profile, Nipissing Bluff Profile (4,000 yr), and Algonquin Bluff Profile (10,500 yr) Superposed at their Midpoint [from Nash (1977)]

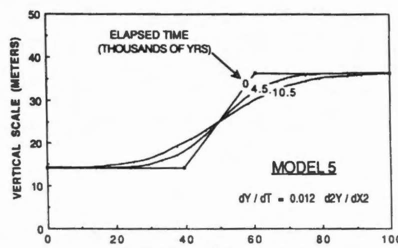

FIG. 14. Slope Profiles Predicted by Model 5 for Initial Planar Slope after 4,000 and 10,500 Years of Elapsed Time Using Diffusion Coefficient of 0.012 m^2/yr and Initial Inclination Similar to Present Wave Cut Bluff [from Nash (1977)]

work indicates that in transport-limited slopes, at least, a planar slope with constant inclination, typical of conventional grading practice, is not a stable, long-term equilibrium slope.

REVEGETATION AND LANDSCAPING

If monotony and uniformity in grading are combined with a uniform or artificial pattern of revegetation, the overall effect is not only sterile and ugly but also ineffective. Successful and attractive revegetation must invoke the same concepts and approaches as landform grading. Vegetation patterns that are found in nature should also be mimicked. Shrubs and other woody vegetation growing on natural slopes tend to cluster in valleys and swales where moisture is more abundant. Random patterns or uniform coverage should be avoided. Instead, the vegetation is placed where it makes sense, i.e., where it has a better chance of surviving and does a better job of holding soil. Trees and shrubs require more moisture, and they also do a better job of stabilizing a soil mantle against shallow mass wasting. Accordingly, it makes sense to cluster them in swales and valleys in a slope (see Fig. 15), where runoff tends to concentrate and evaporation is minimized. Shrubs should also be heavily concentrated along the drainage flow of each swale.

By purposely controlling the drainage patterns on a slope, runoff can be concentrated in concave areas where it is needed or where it can best be handled by woody slope vegetation (see Fig. 16). Conversely, runoff and seepage will be diverted away from convex areas. These areas should be planted with grasses or more drought-tolerance herbaceous vegetation. Irrigation needs are thus reduced by careful control of drainage pattern on a slope and selection of appropriate plantings for different areas.

IMPACT ON DEVELOPMENT COSTS

Design Engineering and Surveying Costs

Design and surveying can be measurably higher if it is initially performed by a team only experienced in conventional methods. Design engineering and construction staking

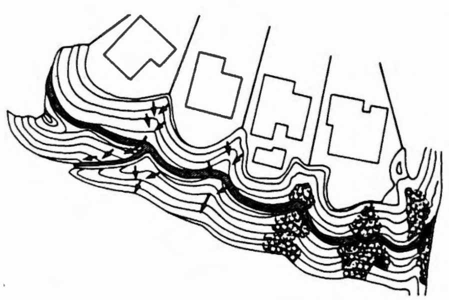

FIG. 15. Topographic Representation of Landform Configuration Showing Radial Flow of Water, Foliage Placement in Swales, and Lots that Conform with Landform Grading Configuration [after Schor (1992)]

FIG. 16. Landform-Graded Slope with Convex and Concave Slope Shapes, Varying Gradient, Curvilinear Drainage Ditch Concealed in Berm and Swale Configuration, and Clustered Plantings

and surveying costs are directly related to the experience, talent, and versatility of the design engineer and his full understanding of the concept. When first implemented with a totally inexperienced staff during pioneering stages, design cost was 15% higher and field cost 10% higher than conventionally designed and surveyed slopes. From that initial experience, design costs quickly decreased to a factor of 1–3%, and surveying to 1–5% over conventional methods and approaches.

A willingness and an open mind to depart from old concepts are essential elements for realizing the benefits of landform grading. In-depth training of the designer, draftsman, and project manager are indispensable, as well, before attempting the landform-grading method. Approving agencies must also be brought into the information dissemination process so that plan check, permitting and, later, inspection can proceed smoothly.

Construction/Grading Costs

Construction/grading costs are most directly related to the size and volume of earth movement than any other factor. In addition, there is a direct relationship to the competitive marketplace situation at a given time. Competition for larger projects, such as those for 1,000,000 cu yd or more, tends to eliminate adherence to landform-grading standards as a significant factor.

Grading costs in hillsides of largely sedimentary materials and not requiring blasting or extremely heavy ripping range from $0.75 to $1.25 per cubic yard with an average of $1.00 per cubic yard. Variables affecting the unit cost include the quantity of material, the nature of the operating area, i.e., open or confined, the length and steepness of the haul from the cut areas to the fill areas, and the rippability by conventional dozer/scraper equipment.

At first glance it appears that landform-graded projects would be significantly more expensive to construct than conventional ones because of the more intricate details and natural shapes required. However, experience has shown that the differential is minor when compared to the total project cost. This is true because the largest percentage (on average 90%) of the earth volume moved, the mass "X" shown in Fig. 17, can be moved, placed, and compacted in a totally conventional manner. Only the outer slope layers, 20–50 ft thick (or approximately 10% of volume), require specialized shaping. Moreover, even this outer layer can still be placed and compacted with conventional equipment and methods. This outer component needs an additional grade checker for control and a dozer with an experienced operator for final shaping. Accordingly, when costs are reckoned on the basis of the actual additional operations involved they are a minor component, typically on the order of 1% of the total cost.

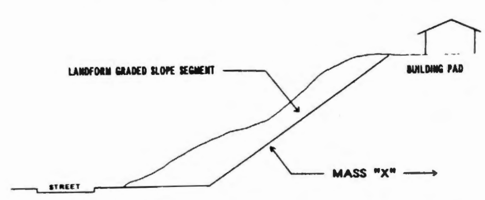

FIG. 17. Relative Amounts and Location of Earth Movement by Conventional as Opposed to Landform Grading

COST-IMPACT COMPARISONS ON VARIOUS SIZE PROJECTS

Large-Scale Projects

On a recently completed hillside project involving 20,000,000 cu yd of earth movement at a cost of some $24,000,000, the total additional cost incurred including design, surveying, construction staking, and grading, was $250,000, or about 1% of the total cost of the grading.

No loss of residential density was encountered, because land planning was done concurrently with the engineering. There was a loss of approximately 1% of commercial pad area due to concave valleys projecting into them. This was offset, however, by the credit given by the governing agency for these indentations toward landscape requirements and coverage calculations for the building pad areas. Furthermore, entitlement approvals were advanced by at least 1 year by being able to mitigate the previous strong community opposition to conventional hillside design and construction methods.

Small-Scale Projects

A 10-acre, 24 custom-lot subdivision requiring 300,000 cu yd of earth movement, initially designed by conventional methods, with little hope for approval, was reconfigured to landform-grading standards. The project applicants had previously proposed conventional grading and had for 2 1/2 years tried to secure permitting agency approvals in a community where grading practices had become a major and highly controversial issue. The governing agency insisted that the applicant apply landform-grading concepts before any further resubmittals. The project was redesigned by adhering to these concepts, and the new layout resulted in 21 lots, a loss of three lots. Design and staking costs also increased by approximately $10,000. However, this revision reduced construction costs by reducing the amount of grading required by 20%. The loss of the lots and additional design costs were further offset by reduced street and storm-drain improvements, tree-removal costs, and an enhanced and aesthetically pleasing project with larger open spaces for each of the lots. This in turn, increased the marketability of the projects. In addition to these benefits, the project received unanimous community approval within 3 months.

APPLICABILITY OF LANDFORM GRADING TO OTHER PROJECTS

In addition to residential and commercial developments the landform-grading concept should lend itself readily to highway slopes. Public objections are often voiced against these highly visible and stark slopes. In addition they are sometimes prone to erosion problems and generation of excess runoff. These problems and objections could be greatly mitigated by the application of this concept, thereby improving public acceptance. This benefit would likely offset any associated additional right-of-way acquisition costs.

Other large earthmoving and shaping projects that result in man-made landforms could also benefit from landform grading. Such projects include sanitary landfills, tailings embankments and mining waste stockpiles, and downstream faces of earthfill dams.

CONCLUSIONS

Grading considerations are very important to the successful stabilization and revegetation of slopes. Conventionally graded slopes can be characterized by essentially planar slope surfaces with constant gradients. Most slopes in nature, however, consist of complex landforms covered by vegetation that grows in patterns that are adjusted to hillside hydrogeology. Analysis of slope evolution models reveals that a planar slope often is not an equilibrium configuration.

Landform-graded slopes, on the other hand, are characterized by a variety of shapes including convex and concave forms that mimic stable natural slopes. Downslope drain devices either follow natural drop lines in the slope or are tucked away and hidden from view in special concave swale and convex berm combinations. Similarly landscaping plants are not placed in random or artificial patterns, but rather in patterns that occur in nature. Trees and shrubs are clustered primarily in concave areas, where drainage tends to concentrate, while drier convex portions are planted primarily with herbaceous ground covers.

Design and engineering costs for landform grading increase approximately 1–3%, and surveying 1–5% over conventional methods. Construction and grading costs are most strongly affected by the volume of earth movement and the competitive market. Accordingly, a landform-grading specification on a large project is not a significant factor. The relatively small increase in the costs of engineering and design are more than offset by improved visual and aesthetic impact, quicker regulatory approval, decreased hillside-maintenance and sediment-removal costs, and increased marketability and public acceptance.

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CHARACTERIZATION OF STREAM FISH ASSEMBLAGES IN SELECTED REGIONS OF MOUNTAIN TOP REMOVAL/VALLEY FILL COAL MINING
(Order no. 1P-0130-NAEX)

TASK 4: PROJECT COMPLETION REPORT

Submitted to:
Mr. Jeffrey Alper
U.S. Environmental Protection Agency
1650 Arch Street
Philadelphia, PA 19103-2029

Submitted by:
Jay R. Stauffer, Jr. and C. Paola Ferreri
School of Forest Resources
Pennsylvania State University

OCTOBER 2002

EXECUTIVE SUMMARY

In West Virginia, mountain top removal/valley fill coal mining targets coal that overlays the Kanawha Formation and the Allegheny Formation found in Lincoln, Wayne, Mingo, Logan, Boone, Wyoming, Raleigh, Kanawha, Fayette, Nicholas, Clay, Webster, and Braxton counties (Fedorko and Blake 1998). Green et al. (2000) provides an overview of the potentially affected watersheds. This type of mining also takes place in the adjacent areas of Kentucky (Howard et al. 2000). Because there is little historical information regarding stream fish populations in the primary region of mountain top removal/valley fill coal mining, the U.S. Fish and Wildlife Service requested that we sample the fish communities at several pre-selected sample sites. The objectives of this study were to 1) characterize the fish communities that exist in the primary region of mountain top removal/valley fill coal mining in West Virginia and Kentucky, 2) determine if any unique fish populations exist in this area, and 3) evaluate the effects of these mining operations on fish populations residing in downstream areas.

During 1999-2000, fish assemblages were sampled in 58 sites in West Virginia located on 1st through 5th order streams, and in 15 sites in Kentucky located on 2nd, 3rd, and 4th order streams (Table 1). The majority of the sample sites were selected in consultation with personnel from U.S. Environmental Protection Agency (USEPA) Region III and Region IV. A few sites were added in the field to enhance the characterization of the fish communities in the primary region of mountain top removal/valley fill coal mining. Sites in West Virginia were assigned an EIS Classification based on U.S. EPA Region III (Green et al. 2000) classification. Sites in Kentucky were assigned an EIS Classification based on Region IV (Howard et al. 2000) classifications. Two sites, a 2nd order in the Island Creek watershed (stations 6) and a 4th order stream in the Mud River watershed (station 22) were sampled during Fall 1999 and Spring 2000, and we determined that collections at these sites were comparable between seasons. However, results from the 1999-2000 sampling effort indicated that not enough reference sites were included to adequately assess the potential effects of mountain top mining/valley fill operations on fish communities in the area. A strong relationship exists between stream size (as described by stream order) and the total number of fish species present (Figure 4). All of

the unmined sites that were to serve as reference sites were located on 1st and 2nd order streams, while sites classified as mined, filled, filled/residential, and mined/residential occurred primarily on 3rd and 4th order streams making direct comparisons between mined and filled sites difficult (Figure 4). As a result, in Fall 2001, eight sites in the Mud River that were classified as filled or filled/residential were re-sampled along with five sites in the Big Ugly and three sites in the Buffalo Creek drainages that were chosen to serve as reference (of the unmined condition) sites in the Guyandotte River system.

At each site, a section of stream was selected for sampling the fish community. The length of the study reach was at least 40 times the stream width, but no longer than 150m (Lyons 1992). We collected fishes making three passes (depletion sampling) with a backpack electrofishing unit. Fishes were preserved in 10% formalin and transferred to the Pennsylvania State University Fish Museum for permanent storage in 50% isopropanol.

Fifty-six species, including two hybrid sunfishes, were collected from the 73 sites in the primary region of mountain top removal/valley fill coal mining in West Virginia and Kentucky and the five sites in the Big Ugly drainage (Table 4). As small headwater streams that harbor founding populations that were derived by stream captures have the greatest potential for the progression from a local deme (interbreeding population) to subspecies/species, we examined *Cottus* populations to look for evidence of speciation. An undescribed Potomac River form closely related to *Cottus cognatus* has been collected in West Virginia (R. L. Raesly, pers. comm.) and an undescribed form endemic to the Bluestone River is expected to occur within the state (Stauffer et al. 1995). Our analysis of *Cottus* populations in this area determined that unique species were not present in the study area. However, elimination of these populations would interrupt selective processes that may in turn result in speciation.

Six sites in West Virginia failed to produce any fish (Table 5). Three of these site were in the unmined category (stations 2, 24, 46), one site was in the mined category (station 31), one site was in the filled category (station 1), and one site was in the filled/residential category (station 37). Details of each collection including numbers per species caught, abundance estimate (if possible to calculate), total biomass caught, and biomass per square meter per species are available in Appendix B.

Due to the confounding effects of drought, small stream size (low stream order), and human impact on reference sites in West Virginia, we could not compare reference (unmined) sites to filled sites directly during the 1999/2000 sampling season. Thus, we concentrated on Kentucky sites and 2^{nd} order streams in the New River Drainage where we had comparable reference (unmined) and filled sites to determine the effects of mountain top mining/valley fill coal mining. Comparison of unmined sites and filled sites in Kentucky and in 2^{nd} order streams in the New River Drainage indicate that mountain top removal/valley fill coal mining has impacted the condition of streams. In general, the numbers of total species and benthic species were substantially lower in filled sites than in mined sites in both Kentucky and 2^{nd} order streams in the New River Drainage (Figures 5-8).

In 2001, we were able to compare the fish samples taken in the mined sites in the Mud River with reference sites sampled in the Big Ugly Creek drainage. Both the Mud River and Big Ugly Creek watersheds are part of the Guyandotte River system. Both the total number of species and the total number of benthic species were greater in the reference sites (median 17 and 6 respectively) than in the filled sites collected in 2001 (median=8 and 1.5). The total number of species collected during 1999/2000 was considerably higher (median = 12.5) than the total number of species collected at the same sites in 2001 (median 8; Figures 9 & 10). Water chemistry analysis revealed that five of the Mud River sites sampled in 2001 had detectable levels of selenium (9.5 – 31.5 µg/L). Sites that were associated with valley fills and had detectable levels of selenium supported fewer species than sites solely associated with valley fills. Although the medians of total number of species present in both groups were equal (median = 8 in both cases), the range associated with sites that had fills and selenium was lower than sites with fills alone (Figure 11). Total number of species was dramatically lower in both, sites classified as filled that had selenium present (Mann-Whitney U Test P=0.008) and sites classified as filled that did not have selenium present (Mann-Whitney U Test P=0.0179), than in unmined sites (median = 17). Total number of benthic species followed a similar trend (medians: unmined = 6, filled & selenium = 0, filled & no selenium = 3; Figure 12). Clearly, a multiple year collecting regimen is needed to see if there continues to be a decrease in the number of species over time in the sites associated with valley fills. It may be that with continued mining, heavy metals will continue to be released into the system and have adverse impacts on the fauna.

INTRODUCTION

The State of West Virginia encompasses 62,890 km^2 and is drained by over 45,000 km of streams. The diversity and distribution of fishes in West Virginia is intimately related to drainage divides. The Potomac and James rivers drain the Atlantic Slope, while the remainder of the state drains to the Gulf of Mexico via the Ohio and Mississippi rivers. The fauna of all West Virginia systems draining into the greater Ohio River are similar in composition and have an interrelated history. The greater Ohio River drainage is chiefly comprised of the Monongehela, Little Kanawha, Kanawha, Guyandotte, and Big Sandy/Tug Fork rivers. The upper Kanawha (New) River system above the 7.3 m Kanawha Falls has a unique fauna with six endemic species; the bigmouth chub (*Nocomis platyrhynchus*), the New River shiner (*Notropis scabriceps*), the Kanawha minnow (*Phenacobius teretulus*), the candy darter (*Etheostoma osburni*), the Kanawha darter (*Etheostoma kanawhae*), and the Appalachia darter (*Percina gymnocephala*); all but *E. kanawhae* occur in West Virginia. For this reason, the New River is treated separately from the greater Ohio River drainage with respect to fish distribution. In the ichthyological literature, New River refers to all of the Kanawha River drainage above Kanawha Falls. Thus, all the collections that we made in the Gauley River are reported as the New River fauna.

The Mississippi River basin is considered to be the primary center of origin and dispersal of freshwater fishes east of the Rocky Mountains. The ancient Teays system, which headed against the Blue Ridge Mountains of North Carolina and Virginia, was proposed as a major route of dispersal of fishes east to the Atlantic Slope and north to the upper Ohio River system. The Ohio River did not exist prior to the Pleistocene; during the Pliocene, the two major systems in the central Appalachians were the Teays and Pittsburgh rivers. The existing New-Kanawha River system is regarded as a remnant of the upper Teays River. The Pittsburgh River was a southern tributary of an ancestral river that flowed through the region now occupied by Lake Erie, Lake Huron, and St. Lawrence River. The Old Upper Ohio, Monongahela, and Youghiogheny rivers were tributaries of this system. Pleistocene glaciations reorganized the Teays and Pittsburgh river systems into drainages similar to those present today.

Three Atlantic Slope streams competed for drainage west of the Blue Ridge Mountains during the Tertiary Period: 1) the Potomac River, flowing through the gap at Harpers Ferry; 2) Goose Creek, flowing from west of Massanutten Mountain eastward through Manassas Gap to its confluence with the lower Potomac; and 3) the Rockfish River, which drained the southern Shenandoah Valley through Rockfish Gap into the present Rivanna River drainage of the James River (Stauffer et al. 1978). Thompson (1939) suggested that all streams heading on the western side of the Blue Ridge flowed northwest. The Potomac River was the first to breach this divide and diverted many of these streams to the Atlantic Ocean. The Teays River drained the area west of the Blue Ridge, north to Buchanan, Virginia and Highland County, Virginia via the Fincastle River, which headed against the Old South River. The drainage of the latter included parts of the present-day James and Shenandoah rivers. The Old South River was apparently a tributary to the Shenandoah River, which headed farther south than it does today. Biological evidence in support of this is the widespread distribution of the torrent sucker (*Thoburnia rhothoeca*) in the southern Potomac River west of the Blue Ridge and its absence to the east and north. The mountain redbelly dace (*Phoxinus oreas*) is found in the James and Shenandoah rivers but may have been introduced to the Potomac system. The bluehead chub (*Nocomis leptocephalus)* is widely distributed in the New, Roanoke, and James rivers and is known northward from the South Fork of the Shenandoah and the South River of the Rapidan in the Rappahannock drainage. The margined madtom (*Noturus insignis*) also may have entered the Atlantic Slope via a Teays-Roanoke connection.

The Greenbrier (New River Drainage) and Potomac rivers oppose each other on the Allegheny Mountain along the Pocahontas County, West Virginia- Highland County, Virginia and Pocahontas-Pendleton County, West Virginia lines. The divide does not appear to have been breached; however, the East and West forks of the Greenbrier River have captured drainage from the more northern Monongahela system, and this route has apparently served as a major avenue for the dispersal of fishes from the Teays system including the rosyside dace (*Clinostomus funduloides*), the tonguetied minnow (*Exoglossum laurae*), and the sharpnose darter (*Percina oxyrhynchus*).

Some of the strongest evidence for a Greenbrier-Monongahela-Potomac route of fish dispersal illustrated by the distribution of the river chub (*Nocomis micropogon*) and the bigmouth chub (*Nocomis platyrhynchus*). The bigmouth chub is endemic to the New River system; introgression has occurred between it and river chub populations of the upper Monongahela, and genes from the bigmouth chub have been carried into river chub populations of the upper Potomac. Schwartz (1965) gave additional evidence that the greenside darter (*Etheostoma blennioides*) may have followed a similar route. Further evidence of this proposed route includes the presence of the rainbow darter (*Etheostoma caeruleum*) from the South Branch of the Potomac River (Esmond and Stauffer 1983).

Wallace (1973) concluded that silerjaw minnows (*Ericymba buccata*) in the Potomac basin were of a Monongahela drainage origin, and Hocutt et al. (1978) hypothesized that the species may have entered the Monongahela by way of the Greenbrier River. The silverjaw minnow probably entered the Susquehanna and Rappahannock rivers from the Potomac. Other species regarded as having entered the Potomac River through the Monongahela River system include the Ohio logperch (*Percina caprodes caprodes*) and the southern blacknose dace (*Rhinichthys atratulus obtusus*), which are confined to the Potomac on the central Atlantic Slope.

The least brook lamprey (*Lampetra aepyptera*) is a western form that entered Atlantic drainages, first through captures involving the New River system in Virginia, and then via coastal migration prior to the development of the Chesapeake Bay. The fantail darter (*Etheostoma flabellare*) probably migrated to the Atlantic Coast by means of a variety of headwater captures involving the New and Monongahela rivers.

The banded sculpin (*Cottus carolinae*) complex apparently originated in the Tennessee system and subsequently invaded the upper Ohio, New, and Potomac rivers. The Teays was a center of dispersal of the mottled sculpin (*Cottus bairdi*). Robins (1961) recognized the Potomac sculpin (C*ottus girardi*) as once thought to be endemic to the Potomac, derived from primitive *C. carolinae* stock.

The above discussion emphasizes the uniqueness and importance of the study area in the evolution and speciation of North American freshwater fishes. The areas that were studied were important in the radiation of many different fish forms (e.g., the six endemic fishes in the New River drainage). It is important to note that speciation is not a phenomenon that occurred a million, a thousand, or even one hundred years ago and then stopped. It is a dynamic event that continues to occur. Populations located in the periphery of the distribution of a given species represent those groups that will most likely be involved in a speciation event (Mayr and Ashlock 1991). Certainly, small headwater streams that harbor founding populations that were derived by stream captures have the greatest potential for the progression from a local deme (interbreeding population), to subspecies/species. For example, an undescribed Potomac River form closely related to *Cottus cognatus* has been collected in West Virginia (R. L. Raesly, pers. comm.) and an undescribed form endemic to the Bluestone River is expected to occur within the state (Stauffer et al. 1995). Thus, we examined *Cottus* populations to look for evidence of speciation. The burying of these systems essentially eliminates the genetic diversity needed to fuel speciation processes.

Mountain top mining for the most part targets coal that overlays the Kanawha Formation and the Allegheny Formation found in Lincoln, Wayne, Mingo, Logan, Boone, Wyoming, Raleigh, Kanawha, Fayette, Nicholas, Clay, Webster, and Braxton counties (Fedorko and Blake 1998). Green et al. (2000) provides an overview of the potentially affected watersheds; the Mud River and Island Creek watersheds are located in the Guyandotte River Drainage, the Clear Fork and Spruce Fork watersheds are located in the Kanawha River Drainage, and the Twentymile Creek watershed is located in the New River Drainage. Because there is little historical information regarding stream fish populations in the primary region of mountain top removal/valley fill (MTM/VF) coal mining, the U. S. Fish and Wildlife Service requested that we sample the fish communities at several pre-selected sample sites. The objectives of this study were to 1) characterize the fish communities that exist in the primary region of mountain top removal/valley fill coal mining in West Virginia and Kentucky, 2) determine if any unique fish populations exist in this area, and 3) evaluate the effects of these mining operations on fish populations residing in downstream areas.

METHODS

Fish communities were sampled at 58 sites in West Virginia located on 1st through 5th order streams, and in 15 sites in Kentucky located on 2nd through 4th order streams during Fall 1999 and Spring 2000 (Table 1). In general, comparisons between unmined sites and filled sites were confounded by stream size, effects of drought, and a lack of adequate reference (unmined) sites that were not impaired by other human impacts (including residences, trash, driving through streams). In an effort to elucidate the effects of MTM/VF operations, we sampled 16 sites during Fall 2001 in the Guyandotte River Basin, eight in the Mud River, five in the Big Ugly, and three in Buffalo Creek (Table 2).

Sample Site Selection Fall 1999/Spring 2000

The majority of the sample sites visited in Fall 1999/Spring 2000 were selected in consultation with personnel from U.S. Environmental Protection Agency (USEPA) Region III and Region IV. A few sites were added in the field to enhance the characterization of the fish communities in the primary region of mountain top removal mining. Green eta al. (2000) provide a general description of each of the watersheds sampled in West Virginia. Sites in West Virginia were assigned an EIS Classification based on U.S. EPA Region III (Green et al. 2000) classification: "unmined" (EIS Class = 0), "mined" (EIS Class = 1), "filled" (EIS Class = 2), "filled/residential" (EIS Class = 3), and "mined/residential" (EIS Class = 4). Only three sites (stations 16, 21, and 27 in Table 1) that we sampled in West Virginia were classified as "mined/residential" (EIS Class = 4); thus, we dropped this category from our analysis due to limited sample size. Two sites, a 2nd order stream in the Island Creek watershed (stations 6) and a 4th order stream in the Mud River watershed (station 22) were sampled during both the Fall 1999 and Spring 2000 index periods to determine the comparability of samples between index periods.

Fifteen sites in Kentucky were selected and assigned an EIS Classification based on Region IV (B. Berrang and H. Howard, U.S. EPA Region IV, personal communication) classifications; these were classified as either "reference" (EIS Class = 0) or "filled" (EIS Class = 2) (Table 1). Howard et al. (2000) provide a general description of the watersheds sampled in Kentucky. Based on on-site observations, EPA personnel reclassified one site (PSU station 66 – EPA

Station 9 – Lost Creek) as “filled/residential” after sampling was completed (Howard et al. 2000). Howard et al. (2000) removed this site from further analysis as it represented only one site in the filled/residential category. As a result, we removed this site from our analysis as well. Due to differences in site classifications and major drainage differences (Ohio River Drainage in WV vs Cumberland and KentuckyRiver Drainages in Kentucky), we analyzed data from the two regions separately.

Sample Site Selection Fall 2001

In Fall 2001, we selected eight sites in the Mud River that were classified as either “filled” or “filled/residential ” in 2nd, 3rd, and 4th order streams for further study (Table 2). In consultation with the USEPA, USFWS, and representatives of the mining companies, we selected sites outside the immediate region of MTM/VF coal mining to serve as reference sites that would characterize the “unmined” condition within the Guyandotte River drainage. Five sites in the Big Ugly watershed (Guyandotte River drainage) and three sites in Buffalo Creek (Guyandotte River drainage) on 2nd, 3rd, and 4th order streams were selected (Table 2). After sampling was completed, J. R. Stauffer was informed that the sites in Buffalo Creek were not good reference sites as they were reported to have been “running orange” earlier in the year (William Booth, caretaker for Chief Logan Park, personal communication). As such, comparisons between sites categorized as “filled” or “filled/residential ” and unmined sites are limited to the five reference sites in the Big Ugly watershed.

Characterization of Fish Communities

At each site, a section of stream that included representative habitat types (riffle, pool, and run habitats) was selected for sampling the fish community. The length of the study reach was at least 40 times the stream width, but no longer than 150m (Lyons 1992). In general, fishes were sampled near the location of the EPA benthic macroinvertebrate sampling stations. We did not sample the exact riffle that was designated as the benthic macroinvertebrate site so as not to disturb that site. Thus, the exact sampling reach for fishes is generally located upstream or downstream of the designated EPA site.

Fishes were collected at each site by making three passes using a backpack electrofishing unit. Collections began at the downstream end of the section and proceeded upstream for the entire section. All fishes from the first pass were placed in a bucket labeled "Collection #1." Two additional collections were made in a similar fashion, and fishes placed in buckets labeled "Collection #2" and "Collection #3." Each collection was preserved separately. Fishes were preserved in 10% formalin and transferred to The Pennsylvania State University Fish Museum for permanent storage in 50% isopropanol. Fishes from each sample were identified to species, enumerated, measured (standard length, mm), and weighed (nearest 0.01g). Total biomass caught was determined for each collection as the product of the average weight of the species and the total number caught. Biomass per square meter sampled was determined by dividing total biomass caught by the total surface area sampled (stream section length in meters x average stream width in the section in meters).

Sampling resulted in three separate counts for each species (corresponding to the electrofishing pass number). These counts were used to estimate abundance of each species using the BASIC program, MicroFish (van Deventer and Platts 1983). The program also calculated the 95% confidence interval associated with the estimate. In most cases, it is assumed that the lower confidence limit was equal to the number caught; thus, only the upper 95% confidence limit was reported. Calculation of abundance using this method (depletion sampling) depends on a continuous decrease in numbers caught with each subsequent electrofishing pass. In some cases, we could not calculate an abundance estimate because the species did not exhibit a normal depletion pattern (i.e., numbers did not decrease with increasing number of electrofishing passes), there were too few individuals caught to make an estimate possible, or all individuals were caught in the first pass.

Evaluation of Mining Effects

The number of species for each of the major drainages sampled in West Virginia (i.e., the Guyandotte, Kanawha, and New River Drainages) during Fall 1999/Spring 2000 was plotted against stream order and categorized by EIS class (i.e., unmined, mined, filled, filled/residential, mined/residential). The number of species that we collected was compared to the number of species that would be expected in relatively unimpacted sites based on historical collections in the Guyandotte River (Stauffer et al. 1989) and the Greenbrier River (Hocutt et al. 1978). The purpose of these historical surveys was to describe the fish community in these river systems. As such, sites were extensively sampled using seines until the investigators deemed that further sampling would not add additional species. Although the sampling effort is different between the historical surveys and our current survey, the historical surveys serve as a benchmark for total number of species in the general area of MTM/VF coal mining prior to the development of these operations. The Guyandotte River collections serve as a baseline for fishes collected in the Guyandotte River Drainage (Mud River and Island Creek) and in the Kanawha River Drainage (Spruce Fork and Clear Fork). The Greenbrier River drains into the New River above Kanawha Falls, and fish communities in the system above the falls are generally considered to be similar (Stauffer et al. 1995). Thus, the historical collections in the Greenbrier River serve as a baseline for our collections in the New River Drainage (Twentymile Creek).

The use of particular attributes of a fish community, such as total number of species or total number of benthic species, to evaluate stream condition is becoming widely accepted (e.g., Karr 1981, Leonard and Orth 1986, Ohio EPA 1987, Davis and Simon 1995, Angermeier et al. 2000). A recent study testing the ability of potential metrics based on attributes of the fish community to distinguish between sites of differing quality in Mid-Atlantic Highland streams found that the total number of species present and the total number of benthic species were most consistently related to site quality (Angermeier et al. 2000). In general, the total number of fish species is expected decrease with increasing degradation (Barbour et al. 1999). However, this number will also vary with stream size (generally increases as stream size increases, e.g. Fausch et al. 1984, Messinger and Chambers 2001), so comparisons of condition between EIS classes must be kept within similar stream orders. Benthic species are generally sensitive to degradation resulting from siltation and benthic oxygen depletion because they feed and reproduce in benthic habitats; thus, we expect the total number of benthic species to decrease with increasing degradation (Barbour et al. 1999). Like the total number of species, the total number of benthic species will also vary with stream size and comparisons between EIS classes must be made between sites in similar stream orders. Benthic species included darter (*Etheostoma spp*. and *Percina spp*), sculpin (*Cottus spp*), and madtom (*Noturus spp*) species.

In addition to the effect of stream size (i.e., stream order), major drainage divides also influence attributes of the fish assemblage and comparisons among site classes based on these attributes (Angermeier et al. 2000). As such, all comparisons between EIS classifications (e.g., comparisons between sites classified as unmined and filled) must be limited to similar stream orders within major drainage basins.

To evaluate differences in attributes of the fish community between EIS classes, we used box-and-whisker plots. These plots display the median (solid line in box), the upper (75^{th} percentile) and lower (25^{th} percentile) quartiles (the solid box), the 10^{th} and 90^{th} percentiles (the whiskers), and any outliers of a population of sites. We used the degree of overlap of the attribute ranges to visually assess differences between the EIS classes. The greatest degree of difference is indicated by no overlap of the interquartile ranges. Overlap between the interquartile ranges that excludes the medians indicates the next greatest difference between EIS classes. Extensive overlap of the interquartile range that includes both medians within the overlap indicates little or no difference between EIS classes (Barbour et al. 1999). Where we had a large enough sample size within EIS class ($n>2$), we also calculated the Mann-Whitney U Test probability to test for statistical significance.

Water Chemistry Analysis – Fall 2001

During Fall 2001, we collected water samples at each of the 16 stations where we sampled fish communities. A single water sample was collected at each site (according to directions provided by the EPA) and sent to the Research Environmental & Industrial Consultants, Inc (REIC) for laboratory analysis of total metals (mg/L of aluminum, iron, arsenic, copper, and selenium) and hardness (as mg/L $CaCO_3$). In addition to the water samples, we measured pH and conductivity in-situ using an Oakton pH testr and TDS Testr 20 respectively.

Determination of Unique Populations

Cottus species were analyzed to determine if unique populations existed within the study area. External counts and measurements followed Stauffer (1991) (Table 3A). Except for gill raker meristics, all counts and measurements were made on the left side of the fish. Morphometric values were expressed as percent standard length (SL) or percent head length (HL).

We analyzed the data to determine which populations of *Cottus bairdi* were different from each other. Morphology has always played an important role in the study of the systematics and evolution of organisms. As part of these studies, attempts have been made to qualify and quantify the shape of the organism. Historically, biological shapes have been delineated by a single measurement or a small number of measurements that have been standardized by the use of ratios. The use of ratios is now generally believed to be statistically invalid when delineating among groups (Humphries et al. 1981, Bookstein et al. 1985, Reyment et al. 1984). Morphological data have been analyzed using principal component analysis. The first principal component has been regarded as a size component, while the additional components are considered to be dependent on the shape of the individual. This technique has also been questioned because there is an effect of size on components other than the first one. Consequently, a sheared principal components analysis was developed by Humphries et al. (1981), which restricts the variation due to size to the first component; the subsequent components are strictly shape related.

Differences in body shape were analyzed using sheared principal component analysis of the morphometric data following Stauffer et al. (1997). Pectoral-fin length and pelvic-fin length were not be included in the analysis, as well as any other variables that were influenced by sex and reproductive stage of the fish. Meristic data were analyzed using principal component analysis. The correlation matrix was factored in the calculation of all principal component analyses, while the covariance matrix was factored in the calculation of the sheared principal components. This analysis ordinated factors independently of a main linear ordination (Reyment et al. 1984). Differences among populations were illustrated by plotting either the sheared second or third principal components of the morphometric data against the first principal components of the meristic data. The minimum polygon cluster of *Cottus* with single chin pores were compared to that formed by *Cottus* with double chin pores.

Determination of Nocomis micropogon and N. platyrhynchus

The river chub (*Nocomis micropogon*) and the bigmouth chub (*N. platyrhynchus*) are easily confused. The bigmouth chub is delineated from all other *Nocomis* species based on the tubercle pattern on the head of breeding males. Historically, the river chub (*N. micropogon*) was not believed to inhabit the New River where the bigmouth chub (*N. platyrhynchus*) occurs. However, there were some fishes collected in Twentymile Creek (New River Drainage) that appeared to resemble *N. micropogon*. Not enough males with breeding tubercles were collected to identify these fishes. As a result, we conducted a shape analysis of these specimens (using the same methods as described above for the analysis of *Cottus* spp, but using different counts and measures described in Table 3B and compared them with known populations of *N. micropogon.*

RESULTS

Fifty-six (56) species, including two hybrid sunfishes, were collected from the 73 sites in the primary region of mountain top removal/valley fill coal mining in West Virginia and Kentucky and the five sites in the Big Ugly Creek watershed (Table 4). Information on the distribution, life history, and biology of each of these 56 species can be found in Appendix A.

Characterization of Fish Communities – Fall 1999/Spring 2000

Six sites in West Virginia failed to produce any fish (Table 5). Three of these site were in the unmined category (stations 2, 24, 46), one site was in the mined category (station 31), one site was in the filled category (station 1), and one site was in the filled/residential category (station 37). Details of each collection including numbers per species caught, abundance estimate (if possible to calculate), total biomass caught, and biomass per square meter per species are available in Appendix B.

Guyandotte River Drainage (Mud River and Island Creek). We sampled fishes at 23 stations in the Guyandotte River drainage (Tables 5 & 6). These collections yielded 5,442 fishes distributed among 30 species. In the Guyandotte River drainage, we sampled five 1st order streams, three unmined and two filled. As expected, these 1st order streams yielded low species diversity. One unmined and one filled site yielded no fish at all. The other unmined site yielded two species (*Rhinichthys atratulus*, *Semotilus atromaculatus*). Only one species, *Rhinichthys atratulus,* was collected at two of the filled sites. Biomass/m^2 and number of individuals/m^2 were highest at the unmined site where fish were collected (Station 5; Table 5).

We made fish collections at nine sites in 2^{nd} order streams. We collected between 1-9 species at each of the unmined sites and 1-12 species at the filled sites (Tables 5 & 6). All of the sites yielded fewer species than collected historically in 2^{nd} order streams in the Guyandotte (Figure1). The highest number of individuals per m^2 and the highest biomass per m^2 were collected at Station 12 (MT-14), which was a filled site (Table 5). The high biomass at this site was largely attributable to the high numbers of *Semotilus atromaculatus* and *Lepomis cyanellus* (Table 6); both species are considered tolerant, and the presence of high numbers of these species is considered to be indicative of environmental stresses (Barbour et al. 1999, Messinger and Chambers 2001).

We collected fish at eight sites in 3^{rd} order streams. The collections yielded between 6-20 species (Tables 5 & 6). All of the sites were classified as filled, filled/residential, or mined/residential. Five of the sites produced more species than historically associated with 3^{rd} order streams in the Guyandotte River drainage (Figure 1).

The two 4^{th} order streams sampled were classified as filled/residential and yielded 19 to 20 fish species, which was a higher number of species expected, based on historical records (Figure 1).

Two stations, 6 (2^{nd} order stream) and 22 (4^{th} order stream), were sampled in both Fall 1999 and Spring 2000. At station 6, we caught only two species, *R. atratulus* and *S. atromaculatus,* each season. During spring, we completed only one pass of electrofishing at station 6 because we caught the same two species in the same relative numbers that we had collected in the fall. At station 22, we caught 20 species during each season. Fifteen of the species were represented in both collections, and, in each collection, we caught an additional five different species. Five species, *Notropis photogenis*, *Noturus miurus*, *Lepomis megalotis*, *Micropterus punctulatus*, and *Micropterus salmoides*, were represented by one individual in the fall sample and were absent in the spring sample. In the spring, *Pimephales notatus* (5), *Moxostoma erythrurum* (1), *Ambloplites rupestris* (1), *Percina caprodes* (3), and *Percina maculata* (1) were represented by a few individuals (number in paretheses following species name), and these were not collected in the fall sample. Because the majority of the species were represented in both fall and spring collections, and those that were different were generally represented by only one or a few individuals, we determined that fall and spring samples in this region are comparable.

Kanawha River Drainage (Clear Fork and Spruce Creek watersheds). We sampled fishes at 22 stations in the Kanawha River Drainage (Tables 5 & 7). These collections yielded 3,792 fishes distributed among 30 species. In the Kanawha River drainage, we sampled one site in a 1st order, unmined stream where no fish were collected.

We made fish collections at eight sites in 2nd order streams. The only unmined site yielded 20 *R. atratulus*. Three mined sites were sampled; one yielded no fish and the other two yielded *S. atromaculatus* and *R. atratulus* in low numbers (Table 6). One site sampled was classified as mined/residential and yielded two species, *R. atratulus* and *Cottus bairdi*. Three species were collected at two sites that were classified as filled and one site classified as filled/residential. All of the sites yielded fewer species than collected historically in 2nd order streams in the Guyandotte (Figure 2). As both the Guyandotte River Drainage and the Kanawha River Drainage are part of the Ohio River system, historical collections in the Guyandotte serve as a baseline for fishes collected in the Kanawha River Drainage (Stauffer et al. 1995).

No unmined 3rd order streams were sampled in the Kanawha River drainage. The mined 3rd order streams produced between 2-6 species, and the filled 3rd order streams yielded between 9-14 species (Tables 5 & 7). Samples from sites classified as filled/residential produced between 0-7 species. Two of these sites yielded the highest biomass (station 36 and 39) that was probably due to the very high number of *Cottus bairdi* collected at these stations (327 and 200 respectively; Tables 5 & 7). Most of the sites sampled in 3rd order streams yielded fewer species than collected historically in 3rd order streams in the Guyandotte River drainage (Figure 2).
We collected fishes at three 4th and one 5th order streams that were classified as filled/residential and found between 13-20 species at each of these sites (Table 5 & 8).

New River Drainage (Twentymile Creek watershed). We sampled fishes at 13 stations in the New River Drainage (Table 7). These collections yielded 1,963 fishes distributed among 23 species (including one sunfish hybrid). We sampled one 1st order, unmined site that yielded no fishes. We sampled fishes in six 2nd order streams. Four of these sites were unmined and yielded 3 – 6 species. Two were filled sites that yielded 3 species each (Tables 5 & 8). All 2nd order sites yielded fewer fish species than would be expected based on historical data (Figure 3). No unmined sites were sampled in 3rd or 4th order streams. Three of four collections from 3rd order streams in this drainage were at sites classified as filled and yielded between 9-17 species (Table 8). One site on a 3rd order stream was classified as mined. The mined site and two of the filled sites yielded a lower number of species than would be expected based on historical data, while one filled site yielded a comparable number of species (Figure 3). Two sites classified as mined/residential were sampled in 4th order streams yielding 9 – 16 species (Table 8).

Kentucky Sites. We sampled fishes at 15 stations in Kentucky (Tables 5 & 9). These collections yielded 5,354 individuals distributed among 36 species (including one sunfish hybrid). Collections at five reference sites, two on 2nd order streams and three on 3rd order streams, yielded 9-20 species. The filled sites on 2nd and 3rd order streams yielded between 2-14 fish species. Eight species (*Ericymba buccata, Lythrurus ardens, Phoxinus erythrogaster, Lepomis megalotis, Etheostoma nigrum, Etheostoma sagitta, Percina maculata,* and *Percina stictogaster*) were only collected at the reference stations (Table 9). Six of these species are classified as moderately tolerant of environmental stresses (Barbour et al. 1999). Information regarding tolerance was not available for two of these species, *E. sagitta* and *P. stictogaster*. Six species (*Nocomis micropogon, Rhinichthys atratulus, Ameiurus natalis, Noturus miurus, Lepomis cyanellus, Etheostoma variatum*) were found only at filled sites (Table 9). Four of these species, *R. atratulus, A. natalis, L. cyanellus, E. variatum,* are classified as tolerant of environmental stress, while the other two species, *Nocomis micropogon* and *Noturus miurus*, are classified as intolerant of environmental stress (Barbour et al. 1999). One 3rd order stream site was classified as filled/residential and yielded 13 species (station 66), while two 4th order stream sites classified as filled yielded between 7-14 species (stations 59 and 73). These three stations were not considered further in the analysis as there was only one filled/residential site and no reference site on a 4th order stream.

Characterization of Fish Communities – Fall 2001

We sampled fishes at 16 stations in the Guyandotte River Drainage during Fall 2001 (Table 10). Three of these stations (79, 80, and 81) were chosen to serve as reference sites for our Mud River filled and filled/residential sites, but were impacted by other sources of degradation (William Booth, caretaker of Chief Logan Park, personal communication). Thus, results concentrate on 13 sites – five reference sites in the Big Ugly watershed and eight "filled" and "filled/residential " sites in the Mud River; unmined and filled sites were sampled on 2nd, 3rd, and 4th order streams. These collections yielded 2,739 fishes distributed among 35 species (Table 11). Details of each collection including numbers per species caught, abundance estimate (if possible to calculate), total biomass caught, and biomass per square meter per species are available in Appendix C.

In general, sites that were categorized as filled or filled/residential yielded fewer species that unmined sites (Tables 10 & 11). We collected fishes at four stations in 2nd order streams. Two unmined sites yielded 12 and 13 species, while two "filled" sites yielded 2 and 6 species. We sampled five 3rd order streams – one unmined, two filled, and two filled/residential. The unmined site yielded 17 species, while the filled sites only yielded 6 and 9 species. The filled/residential sites yielded 8 and 18 species. We collected fishes at four 4th order sites, two unmined and two filled/residential. The unmined sites yielded 21 and 24 species, while the filled/residential sites yielded only 8 and 12 species. Of interest, we collected *Lepomis cyanellus,* a species often indicative of environmental degradation (Karr 1981, Barbour et al. 1999), at seven of the eight Mud River stations and at none of the reference sites (Table 11).

Evaluation of Effects of Mining

Evaluation of MTM/VF coal mining operations on fish communities in the West Virginia samples collected in Fall 1999/Spring 2000 was confounded by differences in stream order (Figure 4). In general, the total number of species is expected to increase as stream size (measured by stream order) increases (Fausch et al. 1984, Messinger and Chase 2001). In our samples from West Virginia, a significant relationship exists between stream order and the total number of species collected at a particular site ($R^2 = 0.5849$; $P < 0.001$). The fact that unmined sites were only available in 1st and 2nd order streams (Figure 4), limited our ability to compare unmined to filled sites directly in most cases. Second order streams in the New River basin (Twentymile Creek watershed) provided one instance where we had unmined (n=4) and filled (n=2) sites available for a given stream order allowing a direct comparison of the site classes.

Comparisons between unmined and filled site classes were possible for sites sampled in Kentucky because we had unmined sites (n=5) and filled sites (n=7) in both 2nd and 3rd order streams. We sampled two unmined sites (stations 62 and 63) and three filled sites (stations 64, 65, and 68) in 2nd order streams, and we sampled three unmined sites (stations 61, 71, and 72) and four filled sites (stations 60, 67, 69, 70) in 3rd order streams. As we had unmined and mined sites in both stream orders, sites were pooled across stream order by site classification for the analysis. We sampled one site (PSU station 66 – EPA station 9: Lost Creek) that was redefined as a EIS class of filled/residential after Region IV EPA visited the site (Howard et al. 2000). This site was removed from our analysis as it represented only one site in this EIS category. We sampled two sites on 4th order streams that were classified as filled; however, we did not sample any 4th order unmined sites. Because of the strong relationship between stream order and number of species present, the 4th order sites were not included inour analysis, as we did not have an appropriate reference condition (unmined sites) for the comparison.

Kentucky Fish Community Attributes: In general, filled sites (median = 7) had a significantly lower number of total species than the unmined sites (median = 12) in Kentucky (Figure 5; Mann-Whitney U Test, P=0.037). Total number of benthic species was also significantly lower in filled sites (median = 1) than in unmined sites (median = 6; Figure 6; Mann-Whitney U Test, P=0.0059).

Second Order Streams in Twentymile Creek Watershed: In the Twentymile Creek watershed, we were able to sample four unmined sites and two filled sites in 2nd order streams allowing a comparison to be made between EIS classes (Figures 7 & 8). Filled sites on 2nd order streams in Twentymile Creek watershed yielded fewer total species (median = 3) and benthic species (median = 0.5) than unmined sites (median = 5.5 and 2.5 respectively).

Guyandotte River Drainage Comparisons – Fall 2001: We compared the total number of species and total number of benthic species collected at five unmined sites on 2nd, 3rd, and 4th order streams in the Big Ugly watershed with collections from eight sites on 2nd, 3rd, and 4th order streams in the Mud River watershed that were classified either as filled or filled/residential (Figures 9 & 10). Both the total number of species and the total number of benthic species were greater in the unmined sites than in the filled sites (total species: unmined median = 17, filled median = 8, Mann-Whitney U Test P=0.0093; benthic species: unmined median = 6, filled median = 1.5, Mann-Whitney U Test P=0.0088). The total number of species collected at the unmined sites (median = 17) was also greater than the total number of species collected at the same set of Mud River sites (filled and filled/residential) during the Fall 1999/Spring 2000 period (median = 12.5). The total number of species collected at the Mud River sites during Fall 1999/Spring 2000 was considerably higher (median = 12.5) than the total number of species collected during Fall 2001 (median = 8; Figure 9). The same trend holds for the total number of benthic species (Figure 10). The total number of benthic species collected at the unmined sites is greater (median = 6) than the number of benthic species collected in the Mud River during Fall 1999/Spring 2000 (median = 4), but this number is greater than the number of benthic species collected at the same stations in Fall 2001 (median = 1.5).

Water chemistry analysis (see results below) revealed that five of the Mud River sites sampled in Fall 2001 had detectable levels of Selenium (range from 9.5 to 31.5 µg/L). Selenium has been documented to toxic effects on aquatic life (Lemly 1993). In fact, mortality of rainbow trout, chinook salmon, striped bass, and bluegill has been documented at concentrations of selenium ranging from 4 to 10 µg/L (Kennedy et al. 2000). As such, we grouped the Mud River sites according to presence (n=5) or absence (n=3) of selenium and repeated the analysis of total number of species and total number of benthic species (Figures 11 & 12). Sites that were associated with valley fills and had detectable levels of selenium supported fewer species than sites solely associated with valley fills. Although the medians of total number of species present in both groups were equal (median = 8 in both cases), the range associated with sites that had fills and selenium was lower than sites with fills alone (Figure 11). Total number of species was dramatically lower in both, sites classified as filled that had selenium present (Mann-Whitney U Test P=0.008) and sites classified as filled that did not have selenium present (Mann-Whitney U

Test P=0.0179), than in unmined sites (median = 17). Total number of benthic species followed a similar trend (medians: unmined = 6, filled & selenium = 0, filled & no selenium = 3; Figure 12).

Water Chemistry Analysis – Fall 2001

Water chemistry analysis detected selenium in five of the eight sites in the Mud River watershed associated with valley fills (Table 12; original data sheets from REIC are included in Appendix D). Stations 7 (MT-18), 17 (upstream of MT-15), 18 (MT-15), 22 (MT-23), and 23 (MT-17) all had detectable levels of selenium present, while stations 12 (MT-14), 19 (MT-07), and 20 (MT-05) did not. Station 17 (MT-15) also had elevated levels of aluminum (10.4 mg/L), iron (43.6 mg/L), and copper (0.027 mg/L) as compared to the other filled or unmined sites. It is interesting to compare these values to those measured at station 18 which was located upstream of station 17 and upstream of the valley fill above station 17 (i.e., stations 17 and 18 essentially bracket a valley fill with station 18 at the upstream end and station 17 at the downstream end). Levels of all detectable metals were lower at station 18 (upstream of the valley fill) than at station 17 (Table 12).

Like the related benthic macroinvertebrate studies in West Virginia (Green et al. 2000) and Kentucky (Hoke et al. 2000), we found elevated values of conductivity and pH at sites associated with valley fills as compared to the unmined sites (Table 12). Conductivity values at the filled and filled/residential sites in the Mud River watershed ranged from 513 to 2330 µmhos/cm with an average of 1716.5 µmhos/cm. These values are substantially higher than conductivity values at the five unmined sites that ranged from 125 to 210 µmhos/cm with an average of 164.2 µmhos/cm. The range of pH values at sites associated with valley fills was higher (7.3 to 8.3) than the range of pH at the reference sites (7.0 to 7.2).

Analysis of <u>Cottus</u> Populations.

Sculpins identified as *Cottus bairdi* had either one or two central chin pores. The number of central chin pores has been used as a diagnostic character to separate eastern sculpin species. Therefore, a series of counts and measurements (Table 2) were made on the collections of *C. bairdi*. A plot of the sheared second principal component of the morphometric data versus the first principal component of the meristic data demonstrated that there was complete overlap between the clusters formed by those *C. bairdi* with two chin pores and those specimens with a single chin pore (Figure 13). Thus, there were no other morphometric or meristic factors that supported the theory that the number of chin pores was an informative character that separated the two populations. Nevertheless, it is important to continue to tract these populations. Ideally, one would want to conduct a series of behavior observations to determine if individuals with one and two chin pores assortatively mate.

Determination of Nocomis micropogon and N. platyrhynchus

A plot of the sheared second principal component of the morphometric data versus the first principal component of the meristic data demonstrated that there was some minor separation between the clusters formed by those known populations of *N. micropogon* and *N. platyrhynchus* (Figure 14). These data are equivocal; hence we identified all specimens collected in Twentymile Creek as *N. platyrhynchus*, but more analyses of these populations are needed.

DISCUSSION

The primary region of mountain top removal/valley fill coal mining in West Virginia encompasses an important region for fish diversity. The Kanawha River harbors 105 native species, four of which may be introduced, and 11 introduced forms, two of which may be native. No endemic forms are reported from the Kanawha River below the falls. The West Virginia portion of the New River has a depauperate fauna, when compared to the Kanawha River. There are 56 native species, six of which are endemic and 12 of which may be introduced, and 30 introduced species, 18 of which may be native. The relatively high degree of endemism and the reduced number of native species is most likely attributable to the presence of Kanawha Falls, which is a major barrier to fish dispersal. A total of 90 native species (three of which may be introduced – see Stauffer et al. 1995) inhabits the Guyandotte River, and an additional five introduced species are reported.

The uniqueness of this area is further emphasized by the fact that we collected high numbers of *Cottus bairdi* with single chin pores. Although our analysis indicates that *Cottus* with single and double chin pores constitute a single species, the fact that both forms occur in relatively even numbers is unusual. In most places, deviations from the norm, such as a single chin pore versus a double chin pore, are rare in the population. Thus, single chin pore *C. bairdi* may be on a different evolutionary trajectory than those with double chin pores that may ultimately lead to speciation. The continued disruption of streams in the area may eliminate the genetic diversity necessary for this process to continue. Certainly, more observations and studies on these forms is warranted.

Determining the effects of mountain top removal/ valley fill coal mining operations on stream fishes in West Virginia was difficult. In the five watersheds we studied in West Virginia, unmined sites (reference condition) were limited to 1st and 2nd order streams. This was primarily because there were no higher order streams in this area that had not been mined in this manner. Unfortunately, it is clear that these sites do not adequately portray a reference condition – one where fish communities would not be disturbed – for several reasons. First, fish diversity generally increases with increasing stream order (Fausch et al. 1984). Thus, our findings our confounded by stream order – a general increase in the number of species found in filled sites relative to unmined sites is really due to the fact that we sampled filled sites in 2nd through 5th order streams which naturally have a higher diversity of fishes. Second, Green et al. (2000) documented that many unmined sites were affected by the drought of 1999 because they were located on smaller streams that were likely to have no surface water flow during drought conditions. Drought, in and of itself, can act as a major perturbation on fish communities. Although fish may recolonize an area after a drought, it will take several years before the fish community resembles that which was in place before the drought. Certainly, the recolonization rate of fishes is slower than other fauna present in these systems. For example, many aquatic insects have aerial components of their life cycle; thus, water falls, polluted areas, and other obstructions to upstream dispersal are not as effective barriers to recolonization. We have anecdotal information that some of our sites were severely impacted by drought. For example, in a study conducted by the U.S. Fish and Wildlife Service in 1998, researchers recorded finding *Cottus spp*. in benthic invertebrate samples from White Oak Branch (Station 32), an unmined, 2nd order stream (C. Tibbott, U.S. Fish and Wildlife Service, personal communication). When we sampled, in May 2000, we found only one species, *Rhinichthys atratulus.* Because *R. atratulus* inhabits the water column and is typically a headwater species, we would expect that this species would recolonize an area quickly after a drought. Sculpins (*Cottus spp*.), however, are benthic species that typically have a restricted home range. This restricted movement hinders the dispersal rate of these fishes, making it more difficult for them to recolonize an area after a drought. The same study by U.S. Fish and Wildlife Service documented many fishes in the pools of Oldhouse Branch (Station 24), an unmined, 1st order stream (C. Tibbott, U.S. Fish and Wildlife Service, personal communication). When we sampled in May 2000, we found no fish at all. The lack of fish during the spring sampling is most likely due to the effects of the drought in 1999.

As a result, we focused our attention on collections on 2nd order streams in the New River Drainage and on 2nd and 3rd order streams in Kentucky to evaluate the effects of mountain top removal/ valley fill coal mining on fish communities. Comparison of unmined sites and filled sites in Kentucky and in the New River Drainage indicate that mountain top removal/valley fill coal mining has had an effect on the number and composition of the fish communities in these streams. Streams classified as filled had lower numbers of total species and benthic species than unmined streams in both areas.

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Table 1. PSU collection number, PSU station number, stream name, corresponding USEPA MT or Station number where applicable, locality, stream order, EIS Class (0=unmined, 1=mined, 2=filled, 3=filled/residential, 4=mined/residential), sample date, drainage, and USEPA MT Basin for fish collections completed during Fall 1999 and Spring 2000 in the primary region of MTM/VF coal mining in West Virginia and Kentucky.

Collection #	PSU Station Number	Stream Name	EPA MT or Station	Locality	Stream order	EIS Class	Sample Date	Drainage	MT Basin
JRS-99-67	1	Hall Fork	MT-57B	of Left Fork of Cow Creek approximately 100 m above confluence with Left Fork	1	2	23 Oct 1999	Guyandotte	Island Creek
JRS-99-69	2	Sang Branch		approximately 100 m upstream of first stream crossing on Sang Branch Road.	1	0	23 Oct 1999	Guyandotte	Island Creek
JRS-00-61	3	Left Fork	MT-58	Left Fork of Cow Creek upstream of Hall Fork	1	2	28 Apr 2000	Guyandotte	Island Creek
JRS-00-62	4	Cow Creek	MT-52	Cow Creek downstream of valley fill	1	2	28 Apr 2000	Guyandotte	Island Creek
JRS-00-67	5	Spring Branch	MT-13	(tributary of Ballard Fork) approximately 500m above mouth	1	0	29 Apr 2000	Guyandotte	Mud River
JRS-99-68 JRS-00-50	6	Left Fork	MT-60	of Cow Creek	2	2	23 Oct 1999 01 Apr 2000	Guyandotte	Island Creek
JRS-00-52	7	Sugartree Branch	MT-18	downstream of grouted spill way	2	2	01 Apr 2000	Guyandotte	Mud River
JRS-00-59	8	Cabin Branch	MT-50	approximately 100m upstream of confluence with Jacks Fork	2	0	28 Apr 2000	Guyandotte	Island Creek
JRS-00-60	9	Left Fork	MT-59	of Cow Creek downstream of Hall Fork	2	2	28 Apr 2000	Guyandotte	Island Creek

Collection #	PSU Station Number	Stream Name	EPA MT or Station	Locality	Stream order	EIS Class	Sample Date	Drainage	MT Basin
JRS-00-64	10	Rushpatch Branch	MT-02	approximately 170m above mouth	2	0	29 Apr 2000	Guyandotte	Mud River
JRS-00-65	11	Lukey Fork	MT-03	above 3rd valley fill approximately one mile above mouth	2	0	29 Apr 2000	Guyandotte	Mud River
JRS-00-68	12	Ballard Fork	MT-14	approximately 100m above mouth	2	2	30 Apr 2000	Guyandotte	Mud River
JRS-00-69	13	Cabin Branch	MT-51	approximately 600m upstream of Copperas Mine Fork	2	0	30 Apr 2000	Guyandotte	Island Creek
JRS-00-91	14	Island Creek		just upstream of mouth of Cow Creek	3	3	31 May 2000	Guyandotte	Island Creek
JRS-99-70	15	Cow Creek	MT-55	along Rt 13 approximately 3.3 miles downstream from Mingo-Logan Coal mine	3	3	23 Oct 1999	Guyandotte	Island Creek
JRS-00-53	16	Mud River	MT-01	downstream of Rushpatch Branch	3	4	02 Apr 2000	Guyandotte	Mud River
JRS-00-54	17	Stanley Fork		upstream of valley fill and upstream of (MT-15)	3	2	02 Apr 2000	Guyandotte	Mud River
JRS-00-55	18	Stanley Fork	MT-15	downstream of valley fill, above beaver ponds	3	2	02 Apr 2000	Guyandotte	Mud River
JRS-00-57	19	Mud River	MT-07	upstream of Ballard fork upstream of Bridge	3	3	03 Apr 2000	Guyandotte	Mud River
JRS-00-58	20	Mud River	MT-05	just upstream of Passenger Fork, downstream of Lukey Fork	3	3	03 Apr 2000	Guyandotte	Mud River
JRS-00-66	21	Mud River	MT-04	just upstream of Lukey Fork	3	4	29 Apr 2000	Guyandotte	Mud River

Collection #	PSU Station Number	Stream Name	EPA MT or Station	Locality	Stream order	EIS Class	Sample Date	Drainage	MT Basin
JRS-99-76 JRS-00-51	22	Mud River	MT-23	approximately 1800 ft downstream of confluence with Connelly Branch	4	3	25 Oct 1999 01 Apr 2000	Guyandotte	Mud River
JRS-00-56	23	Mud River	MT-17	just upstream of Sugartree Branch	4	3	02 Apr 2000	Guyandotte	Mud River
JRS-00-92	24	Oldhouse Branch	MT-42	of Spruce Fork	1	0	31 May 2000	Kanawha	Spruce Fork
JRS-99-71	25	Rockhouse Creek	MT-25B	approximately 0.5 km above Rock House Creek Lake	2	2	24 Oct 1999	Kanawha	Spruce Fork
JRS-99-80	26	Buffalo Fork	MT-64	of Toney Fork approximately .06 mile above confluence	2	2	30 Oct 1999	Kanawha	Clear Fork
JRS-99-81	27	Ewing Fork	MT-69	at mouth	2	4	30 Oct 1999	Kanawha	Clear Fork
JRS-00-73	28	Toney Fork	MT-70	upstream of mouth of Ewing Fork	2	3	08 May 2000	Kanawha	Clear Fork
JRS-00-76	29	Davis Creek	MT-79	at mouth	2	1	09 May 2000	Kanawha	Clear Fork
JRS-00-79	30	Lem Fork	MT-80	at mouth	2	1	09 May 2000	Kanawha	Clear Fork
JRS-00-80	31	Sycamore Creek	MT-82	bove unnamed tributary above MT-82 near AMD plant	2	1	09 May 2000	Kanawha	Clear Fork
JRS-00-93	32	White Oak Branch	MT-39	of Spruce Fork	2	0	31 May 2000	Kanawha	Spruce Fork
JRS-99-72	33	Beech Creek	MT-32	just downstream of Peats Branch	3	2	24 Oct 1999	Kanawha	Spruce Fork
JRS-99-73	34	Pigeonroost Branch	MT-45	downstream of security gate	3	1	24 Oct 1999	Kanawha	Spruce Fork
JRS-99-78	35	Sycamore Creek		below mouth of Right Fork	3	1	29 Oct 1999	Kanawha	Clear Fork

Collection #	PSU Station Number	Stream Name	EPA MT or Station	Locality	Stream order	EIS Class	Sample Date	Drainage	MT Basin
JRS-99-79	36	Toney Fork	MT-62	at Buffalo Fork confluence South East of Clear Fork	3	3	30 Oct 1999	Kanawha	Clear Fork
JRS-99-82	37	Toney Fork	MT-70	approximately 1 km above mouth of Ewing Run	3	3	30 Oct 1999	Kanawha	Clear Fork
JRS-00-70	38	Beech Creek	MT-28	0.9 miles upstream from gate	3	2	30 Apr 2000	Kanawha	Spruce Fork
JRS-00-74	39	Toney Fork	MT-63	above confluence with Buffalo Fork	3	3	08 May 2000	Kanawha	Clear Fork
JRS-00-77	40	Sycamore Creek	MT-85	downstream of Lem Fork	3	1	09 May 2000	Kanawha	Clear Fork
JRS-00-78	41	Sycamore Creek	MT-81	upstream of Lem Fork	3	1	09 May 2000	Kanawha	Clear Fork
JRS-99-74	42	Spruce Fork	MT-40	upstream from Blair Bridge along St Rt 17	4	3	24 Oct 1999	Kanawha	Spruce Fork
JRS-00-71	43	Spruce Fork	MT-46	upstream of Pigeonroost Branch	4	3	01 May 2000	Kanawha	Spruce Fork
JRS-00-72	44	Spruce Fork	MT-47	150m downstream of mouth of Pigeonroost Branch	4	3	01 May 2000	Kanawha	Spruce Fork
JRS-99-75	45	Spruce Fork	MT-48	upstream of bridge in Dobra-starting 80m above bridge	5	3	25 Oct 1999	Kanawha	Spruce Fork
JRS-00-88	46	Laurel Run	MT-93	at confluence with Rader Fork	1	0	11 May 2000	New	Twentymile Creek
JRS-99-86	47	Hughes Fork	MT-98	approximately 500 m above Jim's Hollow	2	2	01 Nov 1999	New	Twentymile Creek
JRS-00-83	48	Twentymile Creek		just upstream of mouth of Rader Fork	3	1	10 May 2000	New	Twentymile Creek
JRS-00-84	49	Neff Fork	MT-87	near mouth	2	2	10 May 2000	New	Twentymile

Collection #	PSU Station Number	Stream Name	EPA MT or Station	Locality	Stream order	EIS Class	Sample Date	Drainage	MT Basin
									Creek
JRS-00-85	50	Neil Branch	MT-95	from mouth to road culvert (40m)	2	0	11 May 2000	New	Twentymile Creek
JRS-00-86	51	Ash Fork		at mouth	2	0	11 May 2000	New	Twentymile Creek
JRS-00-87	52	Rader Fork	MT-91	500 ft upstream of confluence with Neff Fork	2	0	11 May 2000	New	Twentymile Creek
JRS-00-89	53	Rader Fork	MT-94	upstream of confluence with Laurel Run	2	0	11 May 2000	New	Twentymile Creek
JRS-99-84	54	Twentymile Creek		downstream of Ash Fork	3	2	31 Oct 1999	New	Twentymile Creek
JRS-99-85	55	Hughes Fork		below pond	3	2	01 Nov 1999	New	Twentymile Creek
JRS-00-81	56	Rader Fork	MT-86	just 200m upstream of confluence of Twentymile Creek	3	2	10 May 2000	New	Twentymile Creek
JRS-00-82	57	Twentymile Creek		just downstream of mouth of Rader Fork	4	2	10 May 2000	New	Twentymile Creek
JRS-99-83	58	Twentymile Creek		just downstream of Peach Orchard Branch	4	2	31 Oct 1999	New	Twentymile Creek
JRS-00-95	59	Left Fork	8	of Straight Creek at Rt 66 bridge upstream of confluence with Howard Branch	4	2	03 Jun 2000	Cumberland	
JRS-00-96	60	Sims Fork	6	downstream of confluence with Camp Branch	3	2	03 Jun 2000	Cumberland	
JRS-00-97	61	Clear Creek		RT 190 bridge west of Clear Creek Springs, Kentucky Ridge State Forest (reference)	3	0	04 Jun 2000	Cumberland	

Collection #	PSU Station Number	Stream Name	EPA MT or Station	Locality	Stream order	EIS Class	Sample Date	Drainage	MT Basin
JRS-00-94	62	Big Double	12	along Big Double Road (FR1501) down dirt road that is 0.9 road miles upstream of RT 66 (reference)	2	0	02 Jun 2000	Kentucky	
JRS-00-98	63	Sugar Creek	13	on FR1500 approximately 1/2 mile above mouth, 0.8 road miles upstream of RT 66 (reference)	2	0	04 Jun 2000	Kentucky	
JRS-00-99	64	Buffalo Creek	3	just upstream of RT 15 bridge along 1096	2	2	04 Jun 2000	NF Kentucky	
JRS-00-100	65	Grapevine Creek	2	upstream of Clear Fork	2	2	05 Jun 2000	NF Kentucky	
JRS-00-101	66	Lost Creek	9	1.8 road miles upstream of RT 15 along 2446	3	3	05 Jun 2000	NF Kentucky	
JRS-00-102	67	Lick Branch	14	of Ball Fork just above mouth	3	2	05 Jun 2000	NF Kentucky	
JRS-00-103	68	Fugate Fork	5	at mouth	2	2	05 Jun 2000	NF Kentucky	
JRS-00-104	69	Laurel Fork	4	at upper Laurel Fork Road Bridge	3	2	05 Jun 2000	NF Kentucky	
JRS-00-105	70	Long Fork	1	at mouth	3	2	05 Jun 2000	NF Kentucky	
JRS-00-106	71	Clemons Fork	10	0.3 road miles upstream of confluence with Buckhorn Creek in Robinson Forest (reference)	3	0	06 Jun 2000	NF Kentucky	
JRS-00-107	72	Coles Fork	11	in Robinson Forest (reference)	3	0	06 Jun 2000	NF Kentucky	
JRS-00-108	73	Spring Fork	7	of Quicksand Creek just upstream of Hughes Creek	4	2	06 Jun 2000	NF Kentucky	

Table 2. PSU collection number, PSU station number, stream name, corresponding USEPA MT number where applicable, locality, stream order, EIS Class (0=unmined, 1=mined, 2=filled, 3=filled/residential, 4=mined/residential), sample date, drainage, and USEPA MT Basin for fish collections completed during Fall 2001in the primary region of MTM/VF coal mining in the Guyandotte River Drainage of West Virginia.

Collection #	PSU Station number	Stream Name	EPA MT	Locality	Stream order	EIS Class	Sample Date	Drainage	MT Basin
JRS-01-84	7	Sugartree Branch	MT-18	downstream of grouted spill way	2	2	9/14/2001	Guyandotte	Mud River
JRS-01-87	12	Ballard Fork	MT-14	approximately 100m above mouth	2	2	9/14/2001	Guyandotte	Mud River
JRS-01-85	17	Stanley Fork		upstream of valley fill and upstream of (MT-15)	3	2	9/14/2001	Guyandotte	Mud River
JRS-01-86	18	Stanley Fork	MT-15	downstream of valley fill, above beaver ponds	3	2	9/14/2001	Guyandotte	Mud River
JRS-01-88	19	Mud River	MT-07	upstream of Ballard fork upstream of bridge	3	3	9/14/2001	Guyandotte	Mud River
JRS-01-89	20	Mud River	MT-05	just upstream of Passenger Fork, downstream of Lukey Fork	3	3	9/14/2001	Guyandotte	Mud River
JRS-01-82	22	Mud River	MT-23	approximately 1800 ft downstream of confluence with Connelly Branch	4	3	9/14/2001	Guyandotte	Mud River
JRS-01-83	23	Mud River	MT-17	just upstream of Sugartree Branch	4	3	9/14/2001	Guyandotte	Mud River
JRS-01-90	74	Big Ugly		at mouth of Pigeon Roost - (Ref 1)	4	0	9/15/2001	Guyandotte	

Collection #	PSU Station number	Stream Name	EPA MT	Locality	Stream order	EIS Class	Sample Date	Drainage	MT Basin
JRS-01-91	75	Big Ugly		approximately downstream of mouth of Laurel Creek (Ref 2)	4	0	9/15/2001	Guyandotte	
JRS-01-92	76	Back Fork		0.3 mile above confluence with Laurel Creek (Ref 3)	2	0	9/15/2001	Guyandotte	
JRS-01-93	77	Laurel Creek		at confluence of Charley Fork (Ref 4)	2	0	9/15/2001	Guyandotte	
JRS-01-94	78	Laurel Creek		0.9 road miles upstream of confluence w/ Big Ugly Creek (Ref 5)	3	0	9/15/2001	Guyandotte	
JRS-01-95	79	Buffalo Run		approximately 0.25 miles upstream of entrance to Chief Logan State Park (Ref 6)	2	?	9/16/2001	Guyandotte	
JRS-01-96	80	Right Fork		of Buffalo Creek approximately 300 meter upstream of mouth (Ref 7)	1	?	9/16/2001	Guyandotte	
JRS-01-97	81	Buffalo Creek		above confluence with Right Fork of Buffalo Creek (Ref 8)	2	?	9/16/2001	Guyandotte	

Table 3A. Counts and measurements taken on each *Cottus* specimen.

Expressed as Percent Standard Length	Expressed as Percent Head Length	Counts
Head length	Horizontal eye diameter	No. of lateral-line pores
Snout to dorsal-fin origin	Vertical eye diameter	Branchialsteigal rays
Snout to pelvic-fin origin	Snout length	No. chin pores
Greatest body depth	Postorbital head length	No. center chin pores
1st dorsal-fin base length	Interorbital distance	1st dorsal-fin rays
2nd dorsal-fin base length		2nd dorsal-fin rays
Ant. 1st dorsal - ant anal		Pectoral-fin rays
Ant 2nd dorsal - ant. anal		Anal-fin rays
Post. 2nd dorsal - post anal		
Post. 1st dorsal - post. anal		
Post. 2nd dorsal - post. anal		
Post. 2nd dorsal - vent. caudal		
Post. anal - dorsal caudal		
Post. dorsal - pelvic-fin org.		
Anal-fin base length		

Table 3B. Counts and measurements taken on each *Nocomis* specimen.

Expressed as Percent Standard Length	Expressed as Percent Head Length	Counts
Head length	Horizontal eye diameter	Lateral-line scales
Snout to dorsal-fin origin	Vertical eye diameter	Scales above lateral line
Snout to pelvic-fin origin	Snout length	Scales below lateral line
Caudal peduncle depth	Postorbital head length	Dorsal rays
Greatest body depth	Lower jaw length	Anal rays
Body width	Upper jaw length	
	Head depth	
	Gape width	

Table 4. List of species collected in the primary region of mountain top removal / valley fill coal mining in West Virginia and Kentucky during Fall 1999/Spring 2000 and Fall 2001.

Scientific name	Common name
Lampetra aepyptera	Least brook lamprey
Oncorhynchus mykiss	Rainbow trout
Salmo trutta	Brown trout
Campostoma anomalum	Central stoneroller
Clinostomus funduloides	Rosyside dace
Cyprinella galactura	Whitetail shiner
Cyprinella spiloptera	Spotfin shiner
Cyprinus carpio	Common carp
Ericymba buccata	Silverjaw minnow
Luxilus albeolus	White shiner
Luxilus chrysocephalus	Striped shiner
Lythrurus ardens	Rosefin shiner
Nocomis micropogon	River chub
Nocomis platyrhynchus	Bigmouth chub
Notropis ludibundus	Sand shiner
Notropis photogenis	Silver shiner
Notropis rubellus	Rosyface shiner
Notropis telescopus	Telescope shiner
Notropis volucellus	Mimic shiner
Phoxinus erythrogaster	Southern redbelly dace
Pimephales notatus	Bluntnose minnow
Pimephales promelas	Fathead minnow
Rhinichthys atratulus	Blacknose dace
Semotilus atromaculatus	Creek chub
Catostomus commersoni	White sucker
Hypentelium nigricans	Northern hog sucker
Moxostoma erythrurum	Golden redhorse
Ameiurus melas	Black bullhead
Ameiurus natalis	Yellow bullhead
Ameiurus nebulosus	Brown bullhead
Noturus miurus	Brindled madtom
Labidesthes sicculus	Brook silverside
Cottus bairdi	Mottled sculpin
Ambloplites rupestris	Rock bass
Lepomis auritus	Redbreast sunfish
Lepomis cyanellus	Green sunfish
Lepomis cyanellusx L. macrochirus	Sunfish hybrid
Lepomis cyanellus x L. gibbosus	Sunfish hybrid
Lepomis gibbosus	Pumpkinseed
Lepomis macrochirus	Bluegill
Lepomis megalotis	Longear sunfish
Micropterus dolomieu	Smallmouth bass
Micropterus punctulatus	Spotted bass
Micropterus salmoides	Largemouth bass

Scientific name	Common name
Etheostoma baileyi	Emerald darter
Etheostoma blennioides	Greenside darter
Etheostoma caeruleum	Rainbow darter
Etheostoma flabellare	Fantail darter
Etheostoma kennicotti	Stripetail darter
Etheostoma nigrum	Johnny darter
Etheostoma sagitta	Arrow darter
Etheostoma variatum	Variegate darter
Etheostoma zonale	Banded darter
Percina caprodes	Logperch
Percina maculata	Blackside darter
Percina stictogaster	Frecklebelly darter

Table 5. Summary (total number of species, total number of individuals (indivs), total biomass caught, biomass caught per sq. meter sampled, number of individuals (indivs) per sq. meter sampled) of fish collections completed in Fall 1999 and Spring 2000 by PSU station, PSU collection number, and corresponding USEPA MT or Station number where applicable.

PSU Station	Collection #	EPA MT or Station	EIS Class	Stream Order	Area Sampled (m^2)	Total # Species	Total # Indivs	Total Biomass (g)	Biomass (g/m^2)	Indivs per m^2	Drainage
1	JRS-99-67	MT-57B	2	1	136.80	0	0	0.0	0.0	0.0	Guyandotte
2	JRS-99-69		0	1	136.67	0	0	0.0	0.0	0.0	Guyandotte
3	JRS-00-61	MT-58	2	1	273.33	1	12	31.7	0.1	0.0	Guyandotte
4	JRS-00-62	MT-52	2	1	167.20	1	14	45.5	0.3	0.1	Guyandotte
5	JRS-00-67	MT-13	0	1	60.20	2	13	95.8	1.6	0.2	Guyandotte
6	JRS-99-68	MT-60	2	2	322.00	2	59	535.1	1.7	0.2	Guyandotte
6	JRS-00-50[a]	MT-60	2	2	250.00	2 [a]	25 [a]	87.1 [a]	0.35 [a]	0.1[a]	Guyandotte
7	JRS-00-52	MT-18	2	2	217.60	2	9	50.9	0.2	0.0	Guyandotte
8	JRS-00-59	MT-50	0	2	196.80	2	44	73.3	0.4	0.2	Guyandotte
9	JRS-00-60	MT-59	2	2	366.00	1	12	77.3	0.2	0.0	Guyandotte
10	JRS-00-64	MT-02	0	2	218.13	1	3	1.5	0.0	0.0	Guyandotte
11	JRS-00-65	MT-03	0	2	287.00	9	27	171.7	0.6	0.1	Guyandotte
12	JRS-00-68	MT-14	2	2	166.88	12	157	1689.4	10.1	0.9	Guyandotte
13	JRS-00-69	MT-51	0	2	278.25	2	6	44.9	0.2	0.0	Guyandotte
14	JRS-00-91		3	3	1394.50	13	2336	14772.2	10.6	1.7	Guyandotte
15	JRS-99-70	MT-55	3	3	380.00	7	380	2224.3	5.9	1.0	Guyandotte
16	JRS-00-53	MT-01	4	3	383.47	15	438	9944.8	25.9	1.1	Guyandotte

PSU Station	Collection #	EPA MT or Station	EIS Class	Stream Order	Area Sampled (m^2)	Total # Species	Total # Indivs	Total Biomass (g)	Biomass (g/m^2)	Indivs per m^2	Drainage
17	JRS-00-54		2	3	216.00	7	82	424.1	2.0	0.4	Guyandotte
18	JRS-00-55	MT-15	2	3	172.50	6	38	318.2	1.8	0.2	Guyandotte
19	JRS-00-57	MT-07	3	3	538.33	13	291	1019.8	1.9	0.5	Guyandotte
20	JRS-00-58	MT-05	3	3	584.00	20	358	20418.8	35.0	0.6	Guyandotte
21	JRS-00-66	MT-04	4	3	408.63	14	115	1151.5	2.8	0.3	Guyandotte
22	JRS-99-76	MT-23	3	4	573.20	20	511	1650.7	2.9	0 9	Guyandotte
22	JRS-00-51[b]	MT-23	3	4	667.50	20	313	1474.0	2.2	0.5	Guyandotte
23	JRS-00-56	MT-17	3	4	523.75	19	199	2054.6	3.9	0.4	Guyandotte
24	JRS-00-92	MT-42	0	1	40.00	0	0	0.0	0.0	0.0	Kanawha
25	JRS-99-71	MT-25B	2	2	330.33	3	67	497.3	1.5	0.2	Kanawha
26	JRS-99-80	MT-64	2	2	107.33	3	137	371.7	3.5	1.3	Kanawha
27	JRS-99-81	MT-69	4	2	133.79	2	139	248.0	1.9	1.0	Kanawha
28	JRS-00-73	MT-70	3	2	151.43	3	109	372.5	2.5	0.7	Kanawha
29	JRS-00-76	MT-79	1	2	68.80	2	17	114.9	1.7	0.2	Kanawha
30	JRS-00-79	MT-80	1	2	87.00	2	5	5.4	0.1	0.1	Kanawha
31	JRS-00-80		1	2	40.00	0	0	0.0	0.0	0.0	Kanawha
32	JRS-00-93	MT-39	0	2	102.40	1	20	20.6	0.2	0.2	Kanawha
33	JRS-99-72	MT-32	2	3	220.53	14	167	1225.3	5.6	0.8	Kanawha
34	JRS-99-73	MT-45	1	3	111.60	2	43	53.0	0.5	0.4	Kanawha

PSU Station	Collection #	EPA MT or Station	EIS Class	Stream Order	Area Sampled (m^2)	Total # Species	Total # Indivs	Total Biomass (g)	Biomass (g/m^2)	Indivs per m^2	Drainage
35	JRS-99-78		1	3	283.67	6	207	658.4	2.3	0.7	Kanawha
36	JRS-99-79	MT-62	3	3	212.00	7	420	1893.1	8.9	2.0	Kanawha
37	JRS-99-82	MT-70	3	3	50.00	0	0	0.0	0.0	0.0	Kanawha
38	JRS-00-70	MT-28	2	3	406.02	9	90	1110.2	2.7	0.2	Kanawha
39	JRS-00-74	MT-63	3	3	222.13	4	274	2269.5	10.2	1.2	Kanawha
40	JRS-00-77	MT-85	1	3	418.67	2	51	577.6	1.4	0.1	Kanawha
41	JRS-00-78	MT-81	1	3	251.67	2	26	370.6	1.5	0.1	Kanawha
42	JRS-99-74	MT-40	3	4	1372.50	14	498	1406.0	1.0	0.4	Kanawha
43	JRS-00-71	MT-46	3	4	1220.00	13	527	5693.1	4.7	0.4	Kanawha
44	JRS-00-72	MT-47	3	4	1778.00	18	488	7719.6	4.3	0.3	Kanawha
45	JRS-99-75		3	5	1590.00	20	507	4372.7	2.8	0.3	Kanawha
46	JRS-00-88	MT-93	0	1	30.00	0	0	0.0	0.0	0.0	New
47	JRS-99-86	MT-98	2	2	305.00	3	43	203.9	0.7	0.1	New
48	JRS-00-83		1	3	472.00	8	277	883.2	1.9	0.6	New
49	JRS-00-84	MT-87	2	2	234.93	3	89	165.5	0.7	0.4	New
50	JRS-00-85	MT-95	0	2	65.60	5	52	53.9	0.8	0.8	New
51	JRS-00-86		0	2	97.30	6	65	278.8	2.9	0.7	New
52	JRS-00-87	MT-91	0	2	297.87	6	183	564.3	1.9	0.6	New
53	JRS-00-89	MT-94	0	2	88.00	3	13	34.2	0.4	0.1	New

PSU Station	Collection #	EPA MT or Station	EIS Class	Stream Order	Area Sampled (m^2)	Total # Species	Total # Indivs	Total Biomass (g)	Biomass (g/m^2)	Indivs per m^2	Drainage
54	JRS-99-84		2	3	1286.00	17	279	3589.0	2.8	0.2	New
55	JRS-99-85		2	3	301.00	9	327	1041.0	3.5	1.1	New
56	JRS-00-81	MT-86	2	3	296.80	6	149	754.9	2.5	0.5	New
57	JRS-00-82		2	4	1036.50	9	238	2375.1	2.3	0.2	New
58	JRS-99-83		2	4	800.00	16	248	2564.8	3.2	0.3	New
59	JRS-00-95	8	2	4	1350.00	14	430	6061.4	4.5	0.3	Cumberland
60	JRS-00-96	6	2	3	377.67	7	881	2976.0	7.9	2.3	Cumberland
61	JRS-00-97		0	3	1027.48	16	494	7369.3	7.2	0.5	Cumberland
62	JRS-00-94	12	0	2	423.67	20	784	2354.0	5.6	1.9	Kentucky
63	JRS-00-98	13	0	2	231.20	12	559	691.1	3.0	2.4	Kentucky
64	JRS-00-99	3	2	2	173.87	10	91	444.5	2.6	0.5	NF Kentucky
65	JRS-00-100	2	2	2	298.13	6	514	1113.9	3.7	1.7	NF Kentucky
66	JRS-00-101	9	3	3	827.00	13	281	799.8	1.0	0.3	NF Kentucky
67	JRS-00-102	14	2	3	282.13	4	94	349.8	1.2	0.3	NF Kentucky
68	JRS-00-103	5	2	2	102.83	12	112	233.1	2.3	1.1	NF Kentucky
69	JRS-00-104	4	2	3	317.33	14	121	607.0	1.9	0.4	NF Kentucky
70	JRS-00-105	1	2	3	140.40	2	23	192.0	1.4	0.2	NF Kentucky
71	JRS-00-106	10	0	3	211.06	12	654	1205.7	5.7	3.1	NF Kentucky
72	JRS-00-107	11	0	3	117.47	9	220	401.2	3.4	1.9	NF Kentucky

PSU Station	Collection #	EPA MT or Station	EIS Class	Stream Order	Area Sampled (m^2)	Total # Species	Total # Indivs	Total Biomass (g)	Biomass (g/m^2)	Indivs per m^2	Drainage
73	JRS-00-108	7	2	4	426.67	7	76	114.1	0.3	0.2	NF Kentucky

[a]Two collections were completed at Station 6 (JRS-99-68 in Fall 1999 and JRS-00-50 in Spring 2000). The Spring collection, JRS-00-50 consisted of a single pass of electrofishing because of the small size of the stream and the simple fish assemblage (2 species). As such, numbers of individuals caught and biomass caught are most likely underestimated for the Spring sample.

[b]Two collections were completed at Station 22 (JRS-99-76 in Fall 1999 and JRS-00-51 in Spring 2000). Three passes of electrofishing were completed in each case.

Table 6. Total number of individuals of each species collected in the Guyandotte River Drainage by PSU station number (PSU collection number and EPA MT or Station number are available in Table 5). Stream order and EIS class are also included for each station. Two stations (6 and 22) were sampled both during Fall 1999 and Spring 2000 – seasonal collections are designated by F (fall collection) and S (spring collection).

Guyandotte River Fishes

Stream order	1	1	1	1	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	4
EIS Class	*2*	*0*	*2*	*2*	*0*	*2*	*2*	*2*	*0*	*2*	*0*	*0*	*2*	*0*	*3*	*3*	*4*	*2*	*2*	*3*	*3*	*4*	*3*	*3*	*3*
STATION	**1**	**2**	**3**	**4**	**5**	**6F**	**6S**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22F**	**22S**	**23**
Lampetra aepyptera																	10			1	2	1			
Campostoma anomalum												3	11		198	10	64	24	7	36	74	34	145	66	
Clinostomus funduloides												2					41	1							
Ericymba buccata	N	N											2		171	7	17				26	1	5	28	6
Luxilus chrysocephalus													4		1		21			11	45	18	3	27	7
Notropis ludibundus	O	O													360								21	62	12
Notropis photogenis																							1		
Notropis rubellus																							4	3	
Pimephales notatus	F	F											2		352		15			13	16	2		5	23
Pimephales promelas																			2						
Rhinichthys atratulus	I	I	12	14	1	41	22	2	15	12	3	1	1	1	629	231	77	1	1			1			3
Semotilus atromaculatus					12	18	3	7	29			11	45	5	185	73	122	13	11	16	26	29	36	9	9
Catostomus commersoni	S	S										1	8		58	15	28		1	1	57	3	5	4	
Hypentelium nigricans												2			46	35				7	1	4	9	20	8
Moxostoma erythrurum	H	H															2				12			1	2
Ameirus natalis																							1	1	1
Noturus miurus																							1		
Ambloplites rupestris													1								2			1	2
Lepomis cyanellus												3	53		1		8	31	16	30	24	12	60	16	83
Lepomis macrochirus																					1	1	3	1	3
Lepomis megalotis																	1				1		1		4
Micropterus punctulatus																					1		1		
Micropterus salmoides															2								1		2
Etheostoma blennioides															43			6		3	2		37	20	14
Etheostoma caeruleum												2	24		290	9	8	6		82	9	4	114	28	8

Stream order	1	1	1	1	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	4
EIS Class	*2*	*0*	*2*	*2*	*0*	*2*	*2*	*2*	*0*	*2*	*0*	*0*	*2*	*0*	*3*	*3*	*4*	*2*	*2*	*3*	*3*	*4*	*3*	*3*	*3*
STATION	**1**	**2**	**3**	**4**	**5**	**6F**	**6S**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22F**	**22S**	**23**
Etheostoma flabellare													2				15			24	15	2			
Etheostoma nigrum												2	4				9			65	36	3	5	1	6
Etheostoma zonale																				2	6		58	16	4
Percina caprodes																					2			3	2
Percina maculata																								1	
TOTAL INDIVIDUALS	0	0	12	14	13	59	25	9	44	12	3	27	157	6	2336	380	438	82	38	291	358	115	511	313	199
TOTAL SPECIES	**0**	**0**	**1**	**1**	**2**	**2**	**2**	**2**	**2**	**1**	**1**	**9**	**12**	**2**	**13**	**7**	**15**	**7**	**6**	**13**	**20**	**14**	**20**	**20**	**19**

Table 7. Total number of individuals of each species collected in the Kanawha River Drainage by PSU station number (PSU collection number and EPA MT or Station number are available in Table 5). Stream order and EIS class are also included for each station.

Kanawha River Fishes

Stream order	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4	4	4	5
EIS Class	*0*	*2*	*2*	*4*	*3*	*1*	*1*	*1*	*0*	*2*	*1*	*1*	*3*	*3*	*2*	*3*	*1*	*1*	*3*	*3*	*3*	*3*
STATION	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
Lampetra aepyptera																					1	
*Salmo trutta**													3									
Campostoma anomalum	N							N		61		6	5	N	18				28		86	14
Cyprinella spiloptera																						1
Cyprinus carpio	O							O						O					1			
Ericymba buccata																					19	
Luxilus chrysocephalus										2					1				3	30	47	19
Notropis ludibundus	F							F						F					45			46
Notropis photogenis																			2	23	10	8
Notropis rubellus	I							I		1				S					43	94	86	66
Notropis volucellus																				1	12	
Phoxinus erythrogaster	S		1					S						I								
Pimephales notatus										2												4
Rhinichthys atratulus	H	7	107	9	14	11	4	H	20	1	37	111	44	H	9	62	18	6	27	4	12	1
Semotilus atromaculatus		59	29		7	6	1			12	6	41	35		13	2	33	20	35	13	23	1
Catostomus commersoni										3			1		19							
Hypentelium nigricans										4		5	7		6	10			24	27	20	40
Moxostoma erythrurum																					4	
Cottus bairdi				130	88					1		12	327		3	200			187	149	79	6
Ambloplites rupestris																				2	2	8
Lepomis cyanellus		1								24					5							1
Lepomis macrochirus										32					16						1	2
Micropterus dolomieu																			2	13	9	12
Micropterus salmoides										1												
Etheostoma blennioides																			1	7	2	14
Etheostoma caeruleum										18			1						87	160	74	218

Stream order	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4	4	4	5
EIS Class	*0*	*2*	*2*	*4*	*3*	*1*	*1*	*1*	*0*	*2*	*1*	*1*	*3*	*3*	*2*	*3*	*1*	*1*	*3*	*3*	*3*	*3*
STATION	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
Etheostoma flabellare												32										
Etheostoma nigrum										5												15
Etheostoma variatum																						9
Etheostoma zonale																			13	4	1	22
TOTAL INDIVIDUALS	0	67	137	139	109	17	5	0	20	167	43	207	420	0	90	274	51	26	498	527	488	507
TOTAL SPECIES	**0**	**3**	**3**	**2**	**3**	**2**	**2**	**0**	**1**	**14**	**2**	**6**	**7**	**0**	**9**	**4**	**2**	**2**	**14**	**13**	**18**	**20**

**Salmo trutta* were caught outside of the sample reach (therefore are not included in column totals) and were measured and released.

Table 8. Total number of individuals of each species collected in the New River Drainage by PSU station number (PSU collection number and EPA MT or Station number are available in Table 5). Stream order and EIS class are also included for each station.

New River Fishes

Stream order	1	2	3	2	2	2	2	2	3	3	3	4	4
EIS Class	*0*	*2*	*1*	*2*	*0*	*0*	*0*	*0*	*2*	*2*	*2*	*2*	*2*
STATION	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**
Campostoma anomalum			13		7	25	1		27	72		17	63
Cyprinella galactura									18				
Ericymba buccata	N												7
Luxilus albeolus									8			12	30
Luxilus chrysocephalus	O					5			1				
Nocomis platyrhynchus									46	72			15
Notropis rubellus									16				
Notropis telescopus	F								75				3
Notropis volucellus									1				
Pimephales notatus	I								3				1
Rhinichthys atratulus		40	112	72			89	7		46	70	69	
Semotilus atromaculatus	S	2	50	12	4	5	31	3		21	40	53	26
Catostomus commersoni		1	8				4				11	15	4
Hypentelium nigricans	H		1						13	1		10	20
Cottus bairdi			22		1		30	3			3	21	2
Ambloplites rupestris									15				17
Lepomis cyanellus									6	11			11
Lepomis cyanellus x L. macrochirus										1			
Micropterus dolomieu									3				7
Etheostoma blennioides									2				
Etheostoma caeruleum			2		38	17			36	95	1	18	31
Etheostoma flabellare			69	5	2	12	28		5	8	24	23	2
Etheostoma nigrum						1			4				9
TOTAL INDIVIDUALS	0	43	277	89	52	65	183	13	279	327	149	238	248
TOTAL SPECIES	**0**	**3**	**8**	**3**	**5**	**6**	**6**	**3**	**17**	**9**	**6**	**9**	**16**

Table 9. Total number of individuals of each species collected in the Cumberland and Kentucky River Drainages by PSU station number (PSU collection number and EPA MT or Station number are available in Table 5). Stream order and EIS class are also included.

Cumberland & Kentucky River Fishes

Stream order	4	3	3	2	2	2	2	3	3	2	3	3	3	3	4
EIS Class	*2*	*2*	*0*	*0*	*0*	*2*	*2*	*3*	*2*	*2*	*2*	*2*	*0*	*0*	*2*
STATION	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**
Lampetra aepyptera															2
Oncorhynchus mykiss				1											
Campostoma anomalum	94	154	8	100	41	5	1	32	1	7	15		93	113	3
Ericymba buccata					2								44		
Luxilus chrysocephalus	25		4	125	6	1		15		76	39		47	12	
Lythrurus ardens			5	35											
Nocomis micropogon										1					
Notropis ludibundus								1							
Notropis rubellus	3		1					1			3				
Phoxinus erythrogaster			1		108										
Pimephales notatus	37	1	83	68	2	6		1		1	4				3
Rhinichthys atratulus		276				35	294		2		2				
Semotilus atromaculatus	1	306	24	44	95	30	93	80	90	9	28	22	101	54	42
Catostomus commersoni				1		4		2			1				19
Hypentelium nigricans	30	7	15	13		1	6	25		2		1	4		6
Moxostoma erythrurum				3		1									
Ameirus natalis											2				
Noturus miurus										1					
Ambloplites rupestris	26		3	4						1					
Lepomis auritus	39		148												
Lepomis cyanellus						3					3				
Lepomis cyanellus x L. gibbosus								1							
Lepomis macrochirus			88				1		1		6				
Lepomis megalotis				1											
Micropterus dolomieu	6			1				1							
Micropterus punctulatus	11		2												
Etheostoma baileye	4		3	11	21			3		1	5		60	7	
Etheostoma blennioides			1	50	59			3		5	3		19	7	1
Etheostoma caeruleum	115	121	88	196	97		119	116		7	9		75	20	
Etheostoma flabellare	32	16		91	59	5							85	3	
Etheostoma kennicotti	7		20												
Etheostoma nigrum				23	64								124	2	
Etheostoma sagitta				1									1		
Etheostoma variatum										1	1				
Percina maculata				10									1	2	
Percina stictogaster				6	5										
TOTAL INDIVIDUALS	430	881	494	784	559	91	514	281	94	112	121	23	654	220	76
TOTAL SPECIES	**14**	**7**	**16**	**20**	**12**	**10**	**6**	**13**	**4**	**12**	**14**	**2**	**12**	**9**	**7**

Table 10. Summary (total number of species, total number of individuals (indivs), total biomass caught, biomass caught per sq. meter sampled, number of individuals (indivs) per sq. meter sampled) of fish collections completed in Fall 2001 in the Guyandotte River Drainage by PSU station, PSU collection number, and corresponding USEPA MT or Station number where applicable.

PSU Station	Collection #	EPA MT or Station	EIS Class	Stream Order	Area Sampled (m^2)	Total # Species	Total # Indivs	Total Biomass (g)	Biomass (g/m^2)	Indivs per m^2	Basin
7	JRS-01-84	MT-18	2	2	168.27	2	9	99	1.3	0.1	Mud River
12	JRS-01-87	MT-14	2	2	161.50	6	21	362	2.2	0.1	Mud River
17	JRS-01-85		2	3	280.00	9	32	547	2.0	0.1	Mud River
18	JRS-01-86	MT-15	2	3	130.00	6	20	338	2.6	0.2	Mud River
19	JRS-01-88	MT-07	3	3	503.33	8	107	331	0.7	0.2	Mud River
20	JRS-01-89	MT-05	3	3	356.00	18	251	1612	4.5	0.7	Mud River
22	JRS-01-82	MT-23	3	4	700.00	12	107	1290	1.8	0.2	Mud River
23	JRS-01-83	MT-17	3	4	487.50	8	29	1250	2.6	0.1	Mud River
74	JRS-01-90		0	4	906.66	24	504	2258	2.5	0.6	Big Ugly
75	JRS-01-91		0	4	766.66	21	818	2351	3.1	1.1	Big Ugly
76	JRS-01-92		0	2	115.00	12	171	450	3.9	1.5	Big Ugly
77	JRS-01-93		0	2	110.83	13	145	462	4.2	1.3	Big Ugly
78	JRS-01-94		0	3	340.66	17	525	1354	4.0	1.5	Big Ugly
79	JRS-01-95		?	2	347.66	7	668	3691	10.6	1.9	Buffalo Creek
80	JRS-01-96		?	1	77.00	2	144	355	4.6	1.9	Buffalo Creek
81	JRS-01-97		?	2	118.33	2	78	141	1.2	0.7	Buffalo Creek

Table 11. Total number of individuals of each species collected during Fall 2001 in the Guyandotte River Drainage by PSU station number (PSU collection number and EPA MT or Station number are available in Table 10). Stream order and EIS classification is also included.

Guyandotte River Fishes – Fall 2001

Stream Order	2	2	3	3	3	3	4	4	4	4	2	2	3	2	1	2
EIS Class	*2*	*2*	*2*	*2*	*3*	*3*	*3*	*3*	*0*	*0*	*0*	*0*	*0*	*?*	*?*	*?*
STATION	**7**	**12**	**17**	**18**	**19**	**20**	**22**	**23**	**74**	**75**	**76**	**77**	**78**	**79**	**80**	**81**
Lampetra aepyptera						2			30	4		1	4			
Campostoma anomalum		2	1	1		11	29	1	11	56	13	3	29	154		
Clinostomus funduloides						2						5				
Cyprinella spiloptera									11							
Ericymba buccata					1	8			29	16	23	17	50	21		
Luxilus chrysocephalus						1	1	1	81	207	9	2	47			
Notropis ludibundus							1		2	14						
Notropis rubellus									4	3						
Pimephales notatus		1			1	4			80	174	4	5	66	9		
Pimephales promelas			2	3												
Rhinichthys atratulus					6	3					29	18	2	141	92	38
Semotilus atromaculatus	3	13	11	2	50	115	12	4	46	54	50	57	74	314	52	40
Catostomus commersoni		2	2			13		2				2		25		
Hypentelium nigricans				1			2		9	24		1	7	4		
Moxostoma erythrurum									17							
Ameiurus melas			1													
Ameiurus natalis							1	2								
Ameiurus nebulosus				1												
Noturus miurus									4							
Labidesthes sicculus						16										
Ambloplites rupestris								1	1	2			7			
Lepomis cyanellus	6	2	12	12	22	38	16									
Lepomis gibbosus										3						
Lepomis macrochirus			1			1		1	4							
Lepomis megalotis						1		17	19	12	2		23			
Micropterus dolomieu									1	4	2		5			
Micropterus punctulatus						3	1		19	4						
Etheostoma blennioides			1				10		7	26			5			
Etheostoma caeruleum		1	1		10	4	22		22	77	30	24	144			
Etheostoma flabellare					12	16			11	15	5	5	14			
Etheostoma nigrum					5	10	2		84	89	2	5	36			
Etheostoma variatum									4	14			6			
Etheostoma zonale							10		5	16						
Percina caprodes						3										
Percina maculata									3	4	2		6			
TOTAL INDIVIDUALS	9	21	32	20	107	251	107	29	504	818	171	145	525	668	144	78
TOTAL SPECIES	**2**	**6**	**9**	**6**	**8**	**18**	**12**	**8**	**24**	**21**	**12**	**13**	**17**	**7**	**2**	**2**

Table 12. Water chemistry measurements for sites in the Mud River, Big Ugly, and Guyandotte drainages sampled in September 2001. Chemical analyses were conducted by REIC (data sheets available in Appendix D). In-situ pH and conductivity were measured on site using an Oakton pH Testr and an Oakton TDS Testr 20.

PSU Station	PSU Collection No.	EPA MT or Station No.	EIS Class	Stream Order	Total Al mg/L	Total Fe mg/L	Total As mg/L	Total Cu mg/L	Total Se mg/L	Hardness mg/L as CaCO3	In-situ pH	In-situ Conduct. µmhos/cm
7	JRS-01-84	MT-18	2	2	0.147	0.308	ND	ND	0.0315	1510.0	7.6	2290
12	JRS-01-87	MT-14	2	2	0.514	1.440	ND	ND	ND	1330.0	7.9	1953.00
17	JRS-01-85		2	3	0.437	0.854	ND	ND	0.0095	1520.0	8.2	2330
18	JRS-01-86	MT-15	2	3	10.400	43.600	ND	0.027	0.0158	1660.0	8.3	2160
19	JRS-01-88	MT-07	3	3	0.117	0.318	ND	ND	ND	267.0	8.0	530.00
20	JRS-01-89	MT-05	3	3	0.174	1.330	ND	ND	ND	245.0	7.3	513.00
22	JRS-01-82	MT-23	3	4	0.177	0.250	ND	ND	0.0121	1140.0	7.9	1836.00
23	JRS-01-83	MT-17	3	4	0.154	0.398	ND	ND	0.0107	1380.0	8.1	2120
74	JRS-01-90		0	4	0.077	1.060	ND	ND	ND	72.9	7.1	210.00
75	JRS-01-91		0	4	0.138	0.560	ND	ND	ND	76.7	7.0	206.00
76	JRS-01-92		0	2	0.092	0.125	ND	ND	ND	73.6	7.2	137.00
77	JRS-01-93		0	2	0.296	1.330	ND	ND	ND	60.4	7.0	143.00
78	JRS-01-94		0	3	0.064	0.500	ND	ND	ND	48.8	7.0	125.00
79	JRS-01-95		?	2	0.146	0.062	ND	ND	ND	407.0	6.4	883.00
80	JRS-01-96		?	1	0.089	0.088	ND	ND	ND	129.0	6.5	280.00
81	JRS-01-97		?	2	0.158	0.075	ND	ND	ND	441.0	6.3	926.00

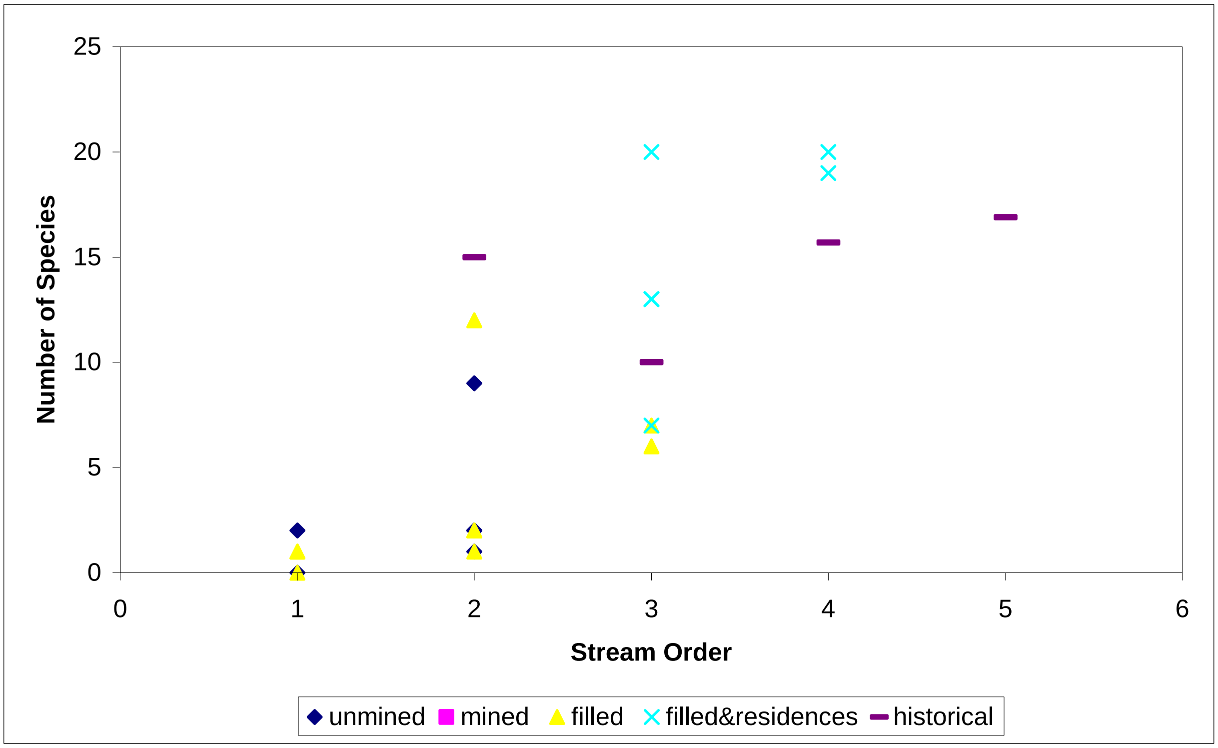

Figure 1. Comparison of number of species found in the Guyandotte River drainage (Mud River and Island Creek watersheds) in sites classified as unmined, mined, filled, filled/residential, and mined/residential and number of species recorded in historical collections in the Guyandotte River by stream order (Stauffer et al. 1989).

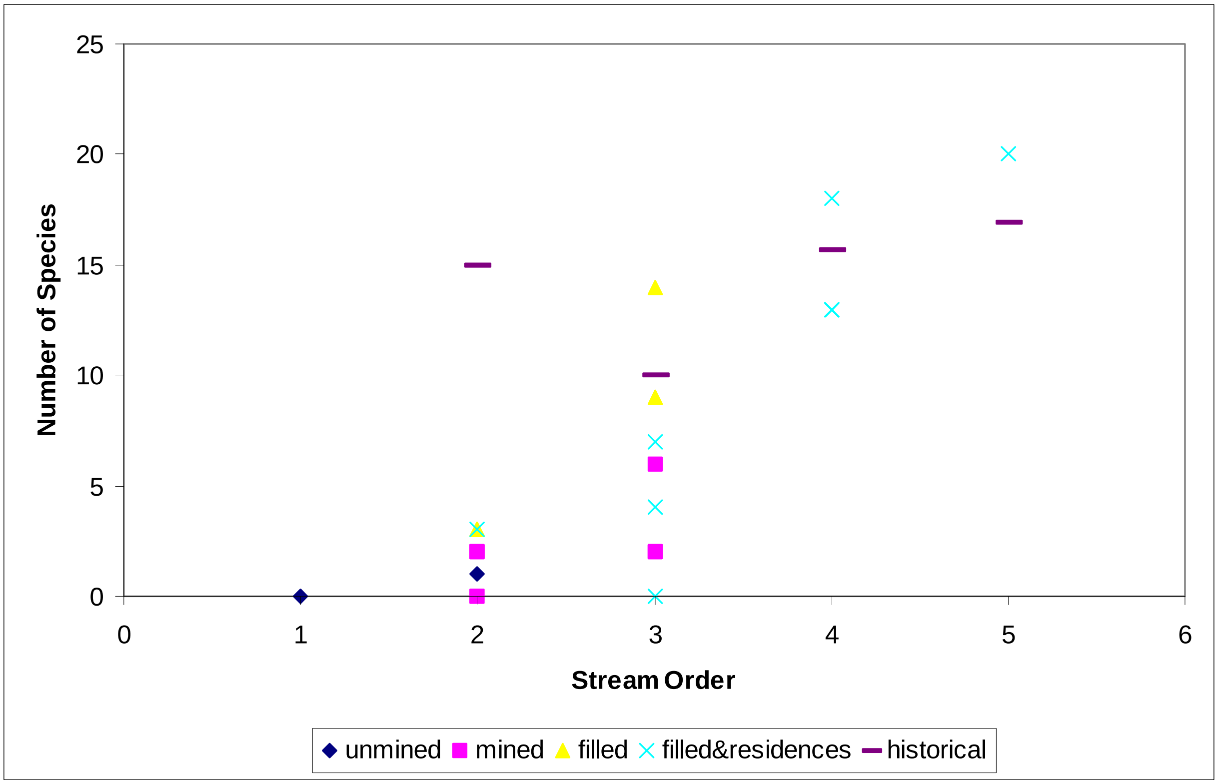

Figure 2. Comparison of number of species found in the Kanawha River drainage (Spruce Fork and Clear Fork watersheds) in sites classified as unmined, mined, filled, filled/residential, and mined/residential and number of species recorded in historical collections in the Guyandotte River by stream order (Stauffer et al. 1989). Because the Guyandotte River Drainage and the Kanawha River Drainage below Kanawha Falls are in the Ohio River system, fish communities are similar and historical collections from the Guyandotte River can serve as baseline for Kanawha River drainage collections.

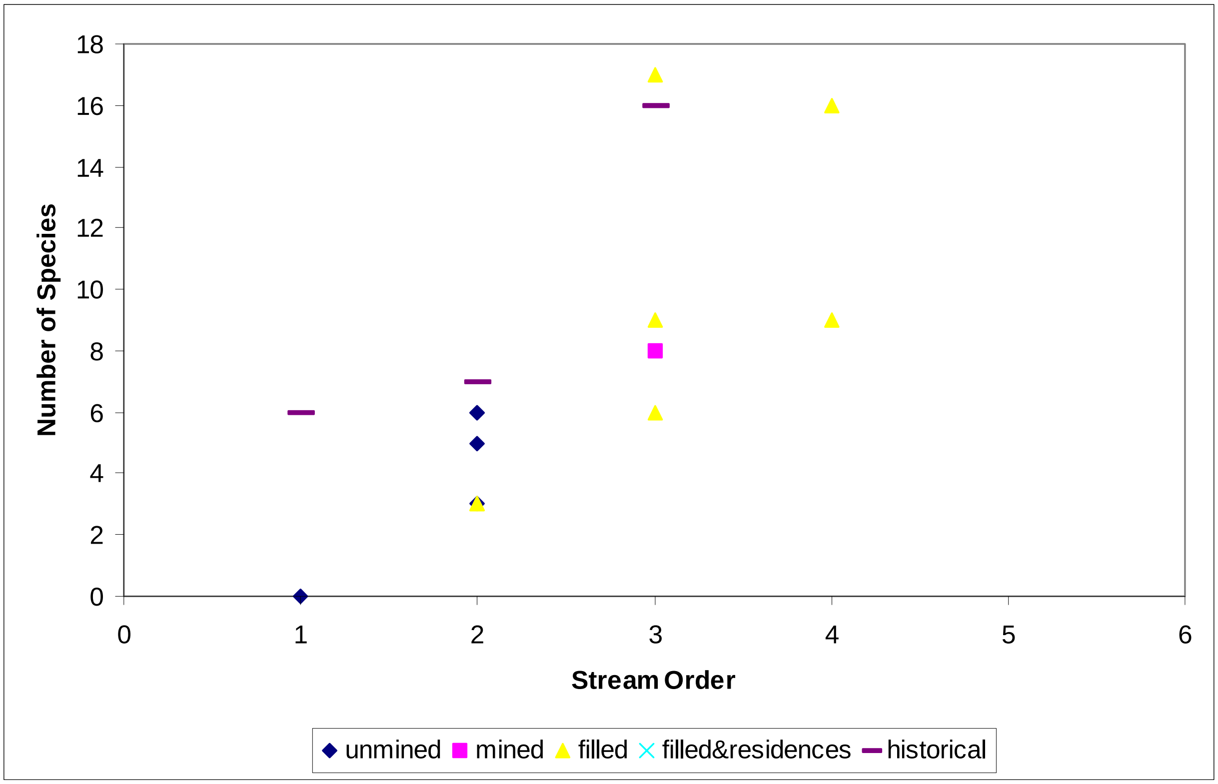

Figure 3. Comparison of number of species found in the New River drainage (Twentymile Creek watershed) in sites classified as unmined, mined, filled, filled/residential, and mined/residential and number of species recorded in historical collections in the Greenbrier River by stream order (Hocutt et al. 1978).

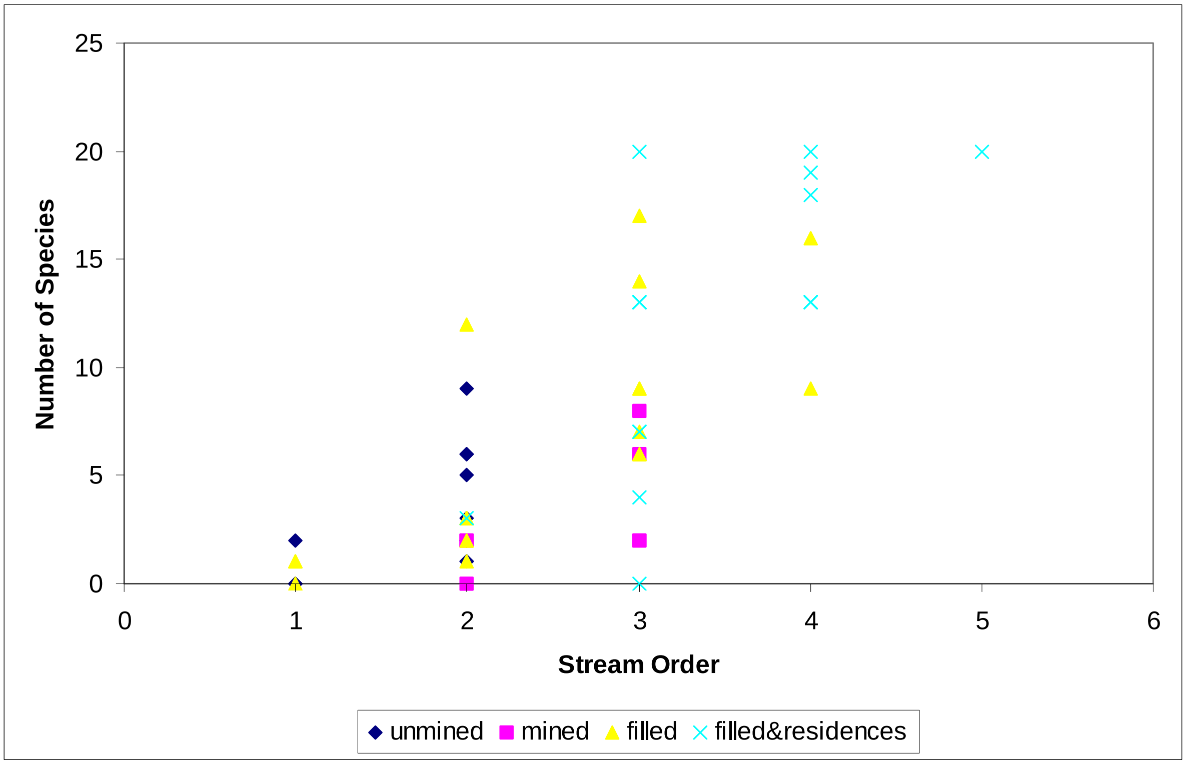

Figure 4. Relationship between total number of species collected and stream order sampled by EIS classification for 58 sites sampled in West Virginia. As stream order increases, the total number of species present increases ($R^2 = 0.5849$; $P < 0.001$). Unmined sites are located only on 1st and 2nd order streams while most of the mined, filled, filled/residential sites occur on 3rd, 4th, and 5th order streams.

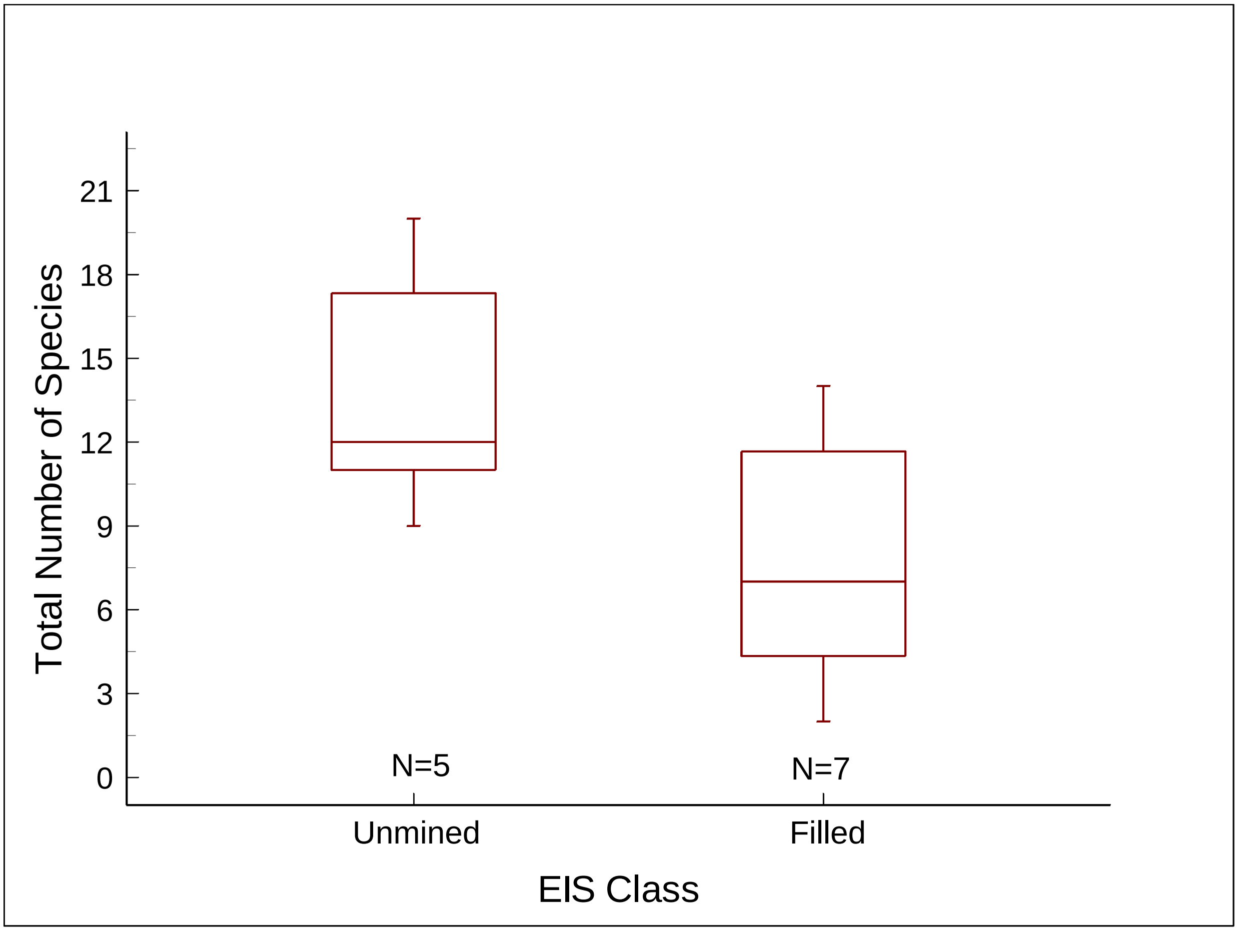

Figure 5. Comparison of number of total number of species between unmined (EIS Class = 0) and filled (EIS = 2) sites in 2nd and 3rd order streams in Kentucky. Sites were pooled across stream order for this analysis because we sampled both filled and unmined sites in both stream orders (two unmined sites and three filled sites in 2nd order streams, three unmined sites and four filled sites in 3rd order streams).

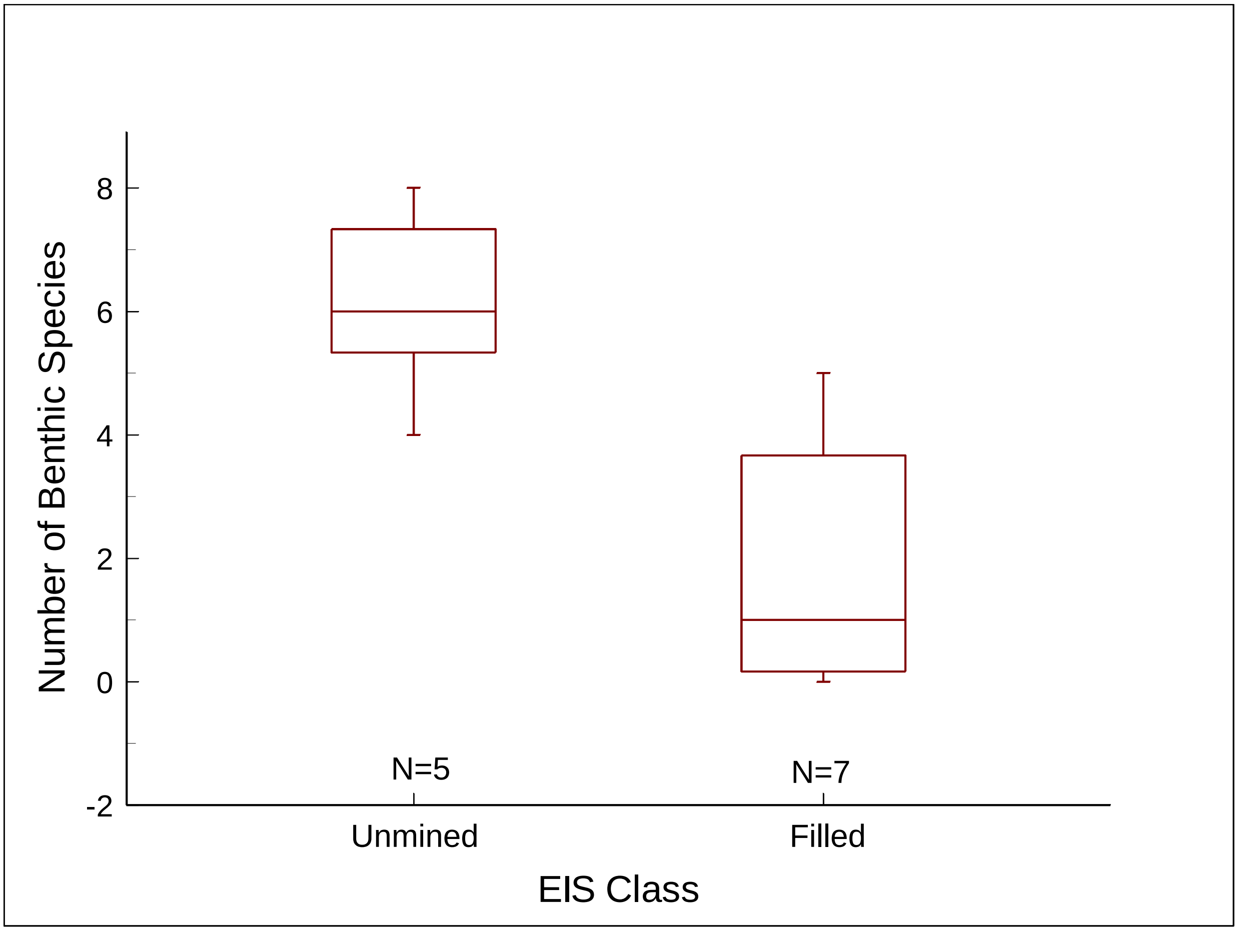

Figure 6. Comparison of number of benthic species between unmined (EIS Class = 0) and filled (EIS = 2) sites in sites in 2nd and 3rd order streams in Kentucky. Sites were pooled across stream order for this analysis because we sampled both filled and unmined sites in both stream orders (two unmined sites and three filled sites in 2nd order streams, three unmined sites and four filled sites in 3rd order streams).

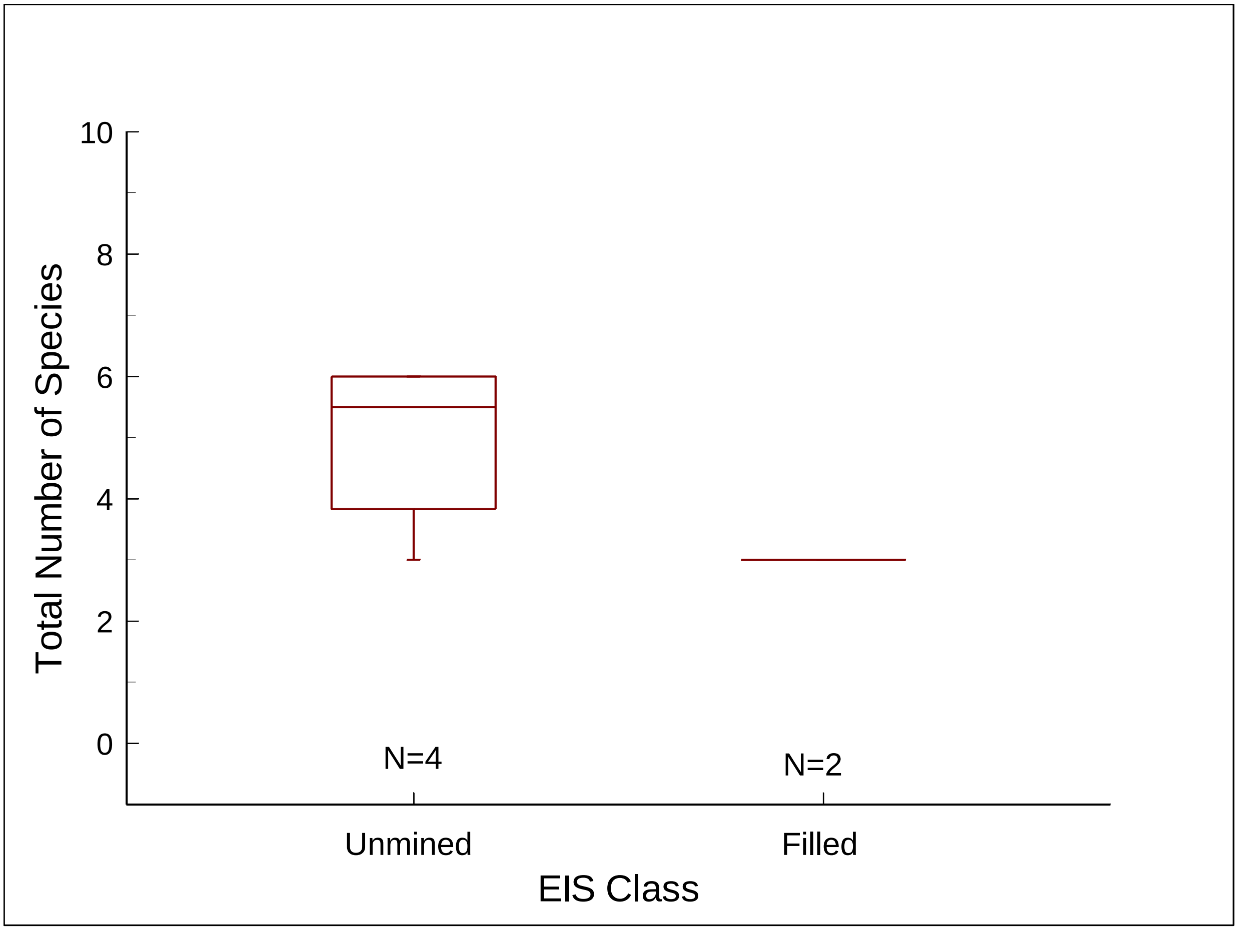

Figure 7. Comparison of total number species between unmined (EIS Class = 0) and filled (EIS = 2) sites in second order streams in Twentymile Creek watershed, West Virginia.

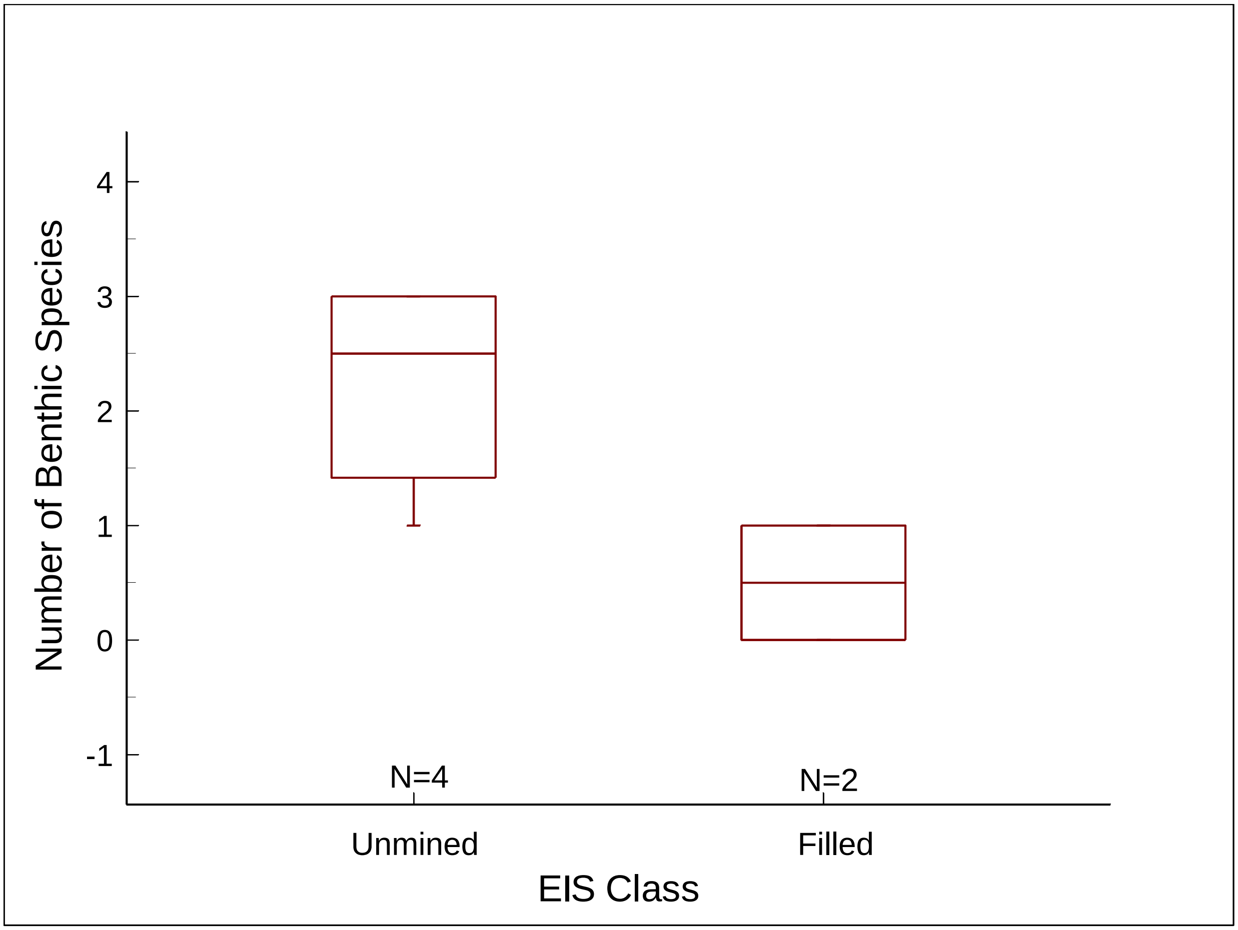

Figure 8. Comparison total number of benthic species between unmined (EIS Class=0) and filled (EIS = 2) sites in second order streams in Twentymile Creek watershed, West Virginia.

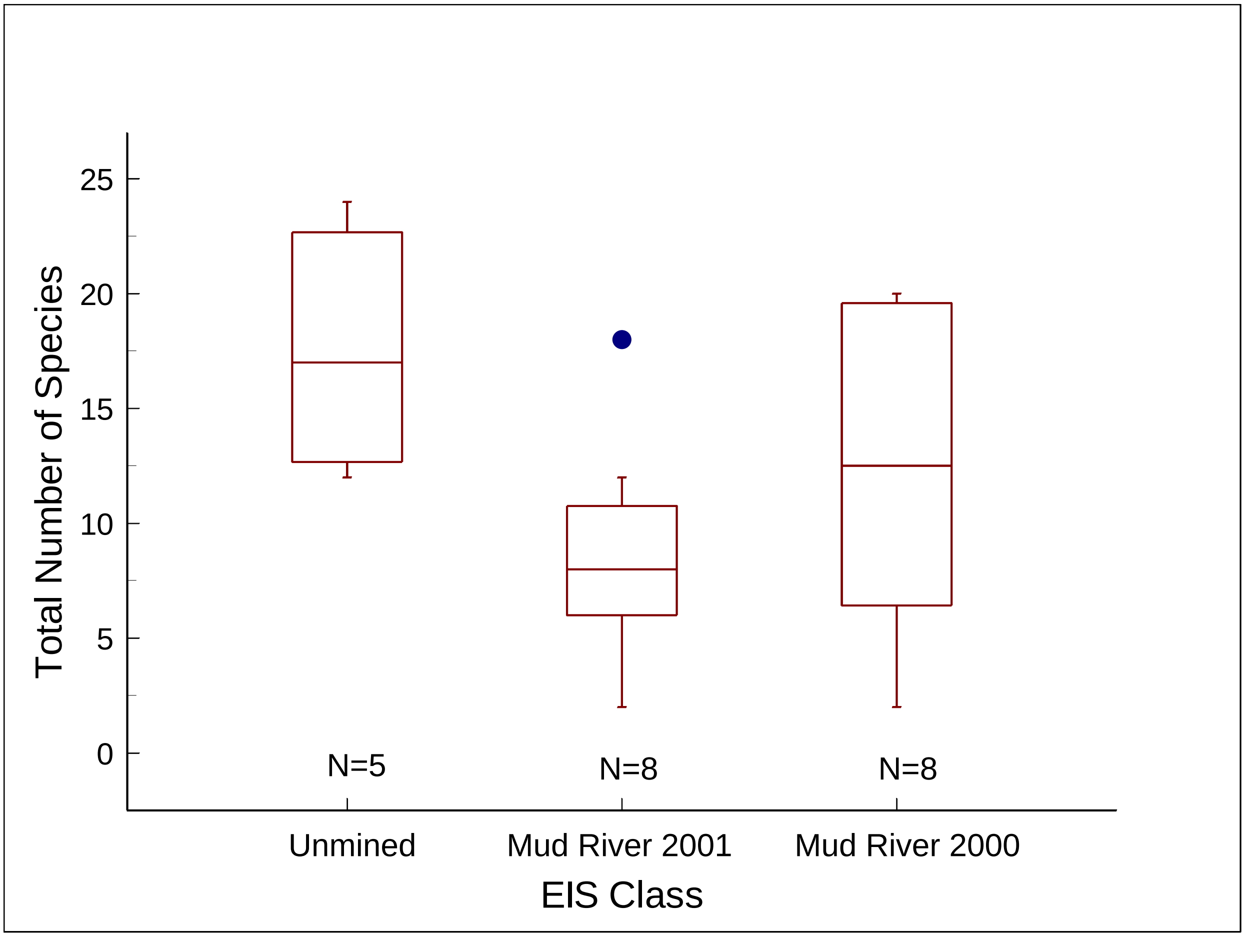

Figure 9. Comparison of total number of species between unmined (EIS Class=0) in the Big Ugly watershed and combined filled (EIS = 2) and filled/residential (EIS=3) sites in the Mud River watershed, West Virginia. The eight sites in the Mud River were sampled both in Fall 2001 (Mud River 2001) and in Fall 1999 and Spring 2000 (Mud River 2000). Sites in the Big Ugly were only sampled in Fall 2001. Comparison of collections in unmined and filled sites in Fall 2001 indicate that unmined sites had greater number of species than filled sites (unmined median = 17, filled (Mud River 2001) = 8, Mann-Whitney U Test P=0.0093).

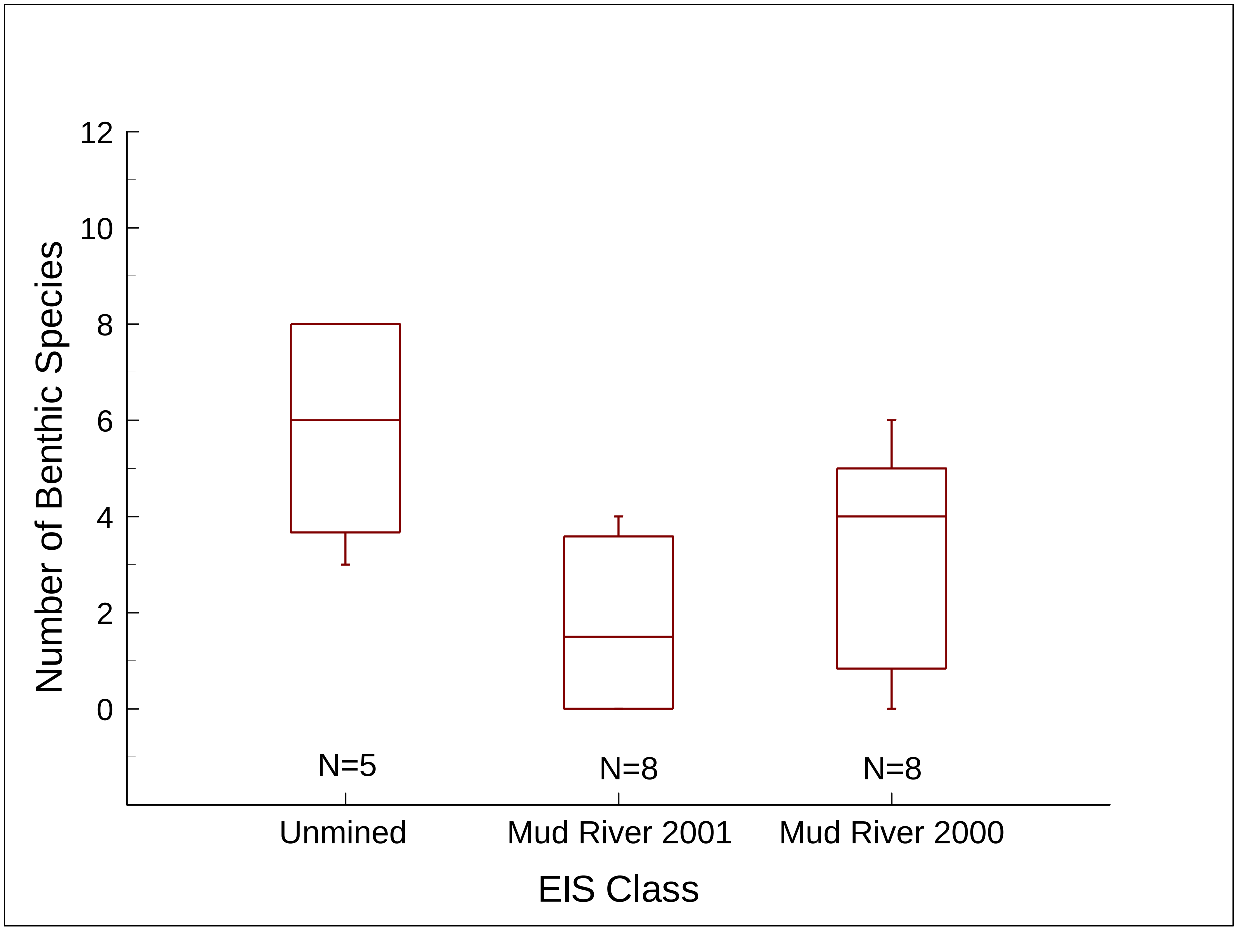

Figure 10. Comparison of total number of benthic species between unmined (EIS Class=0) in the Big Ugly watershed and combined filled (EIS = 2) and filled/residential (EIS=3) sites in the Mud River watershed, West Virginia. The eight sites in the Mud River were sampled both in Fall 2001 (Mud River 2001) and in Fall 1999 and Spring 2000 (Mud River 2000). Sites in the Big Ugly were only sampled in Fall 2001. Comparison of collections in unmined and filled sites in Fall 2001 indicate that unmined sites had greater number of benthic species than filled sites (unmined median = 6, filled (Mud River 2001) = 1.5, Mann-Whitney U Test P=0.0088).

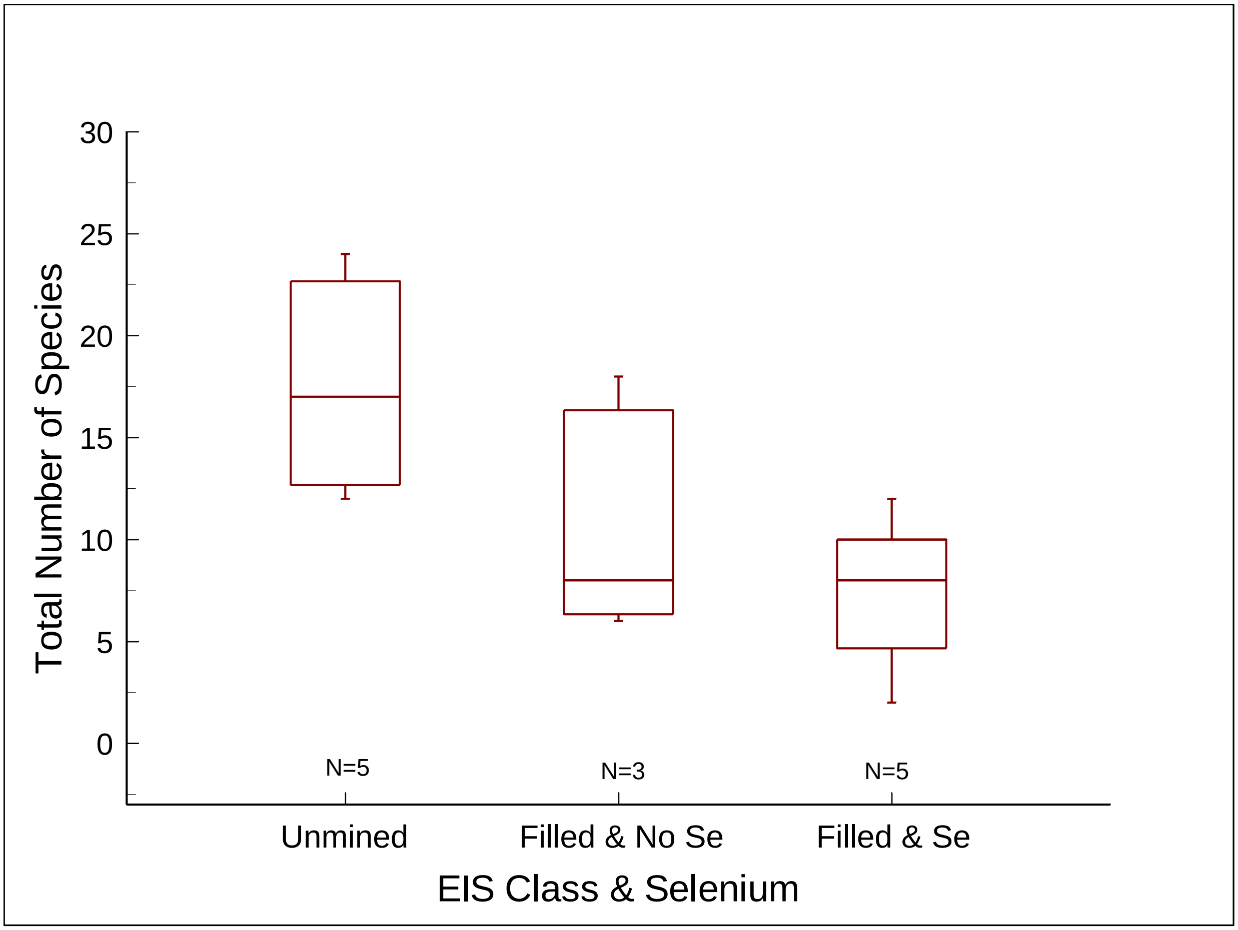

Figure 11. Comparison total number of species collected in Fall 2001 in the Big Ugly and Mud River watersheds. Sites in the Big Ugly were unmined (EIS Class=0) and had no detectable selenium. Sites in the Mud River were a combination of filled (EIS = 2) and filled/residential (EIS=3) categories. Three stations sampled in Fall 2001 in the Mud River did not have detectable levels of selenium (PSU stations 12, 19, 20) while five sites had detectable levels of selenium (PSU stations 7, 17, 18, 22, 23). Total number of species was dramatically lower in sites classified as filled with selenium (median = 8, Mann-Whitney U Test P=0.008) and sites classified as filled without selenium (median = 8, Mann-Whitney U Test P=0.0179) than in unmined sites (median = 17).

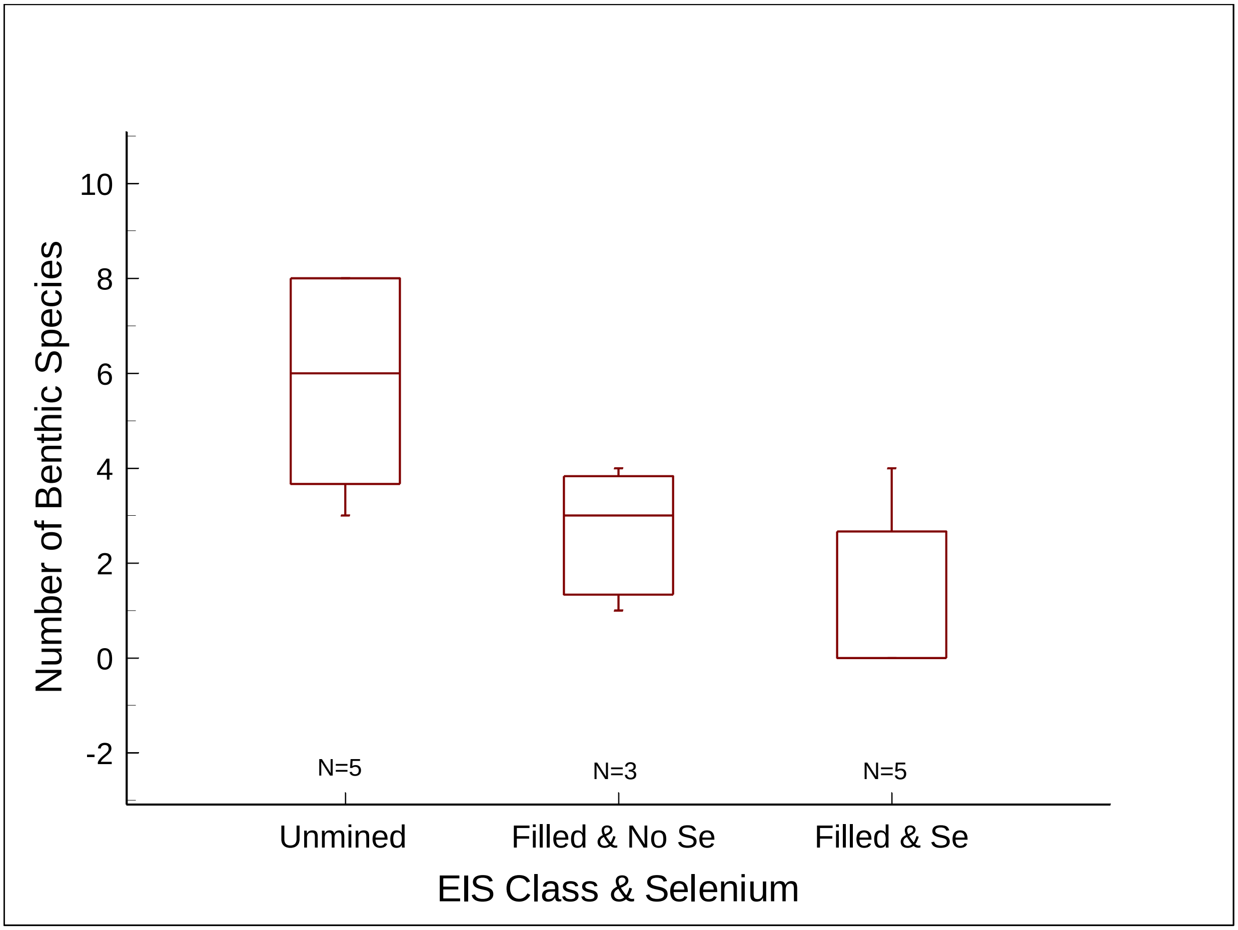

Figure 12. Comparison total number of benthic species collected in Fall 2001 in the Big Ugly and Mud River watersheds. Sites in the Big Ugly were unmined (EIS Class=0) and had no detectable selenium. Sites in the Mud River were a combination of filled (EIS = 2) and filled/residential (EIS=3) categories. Three stations sampled in Fall 2001 in the Mud River did not have detectable levels of selenium (PSU stations 12, 19, 20) while five sites had detectable levels of selenium (PSU stations 7, 17, 18, 22, 23).

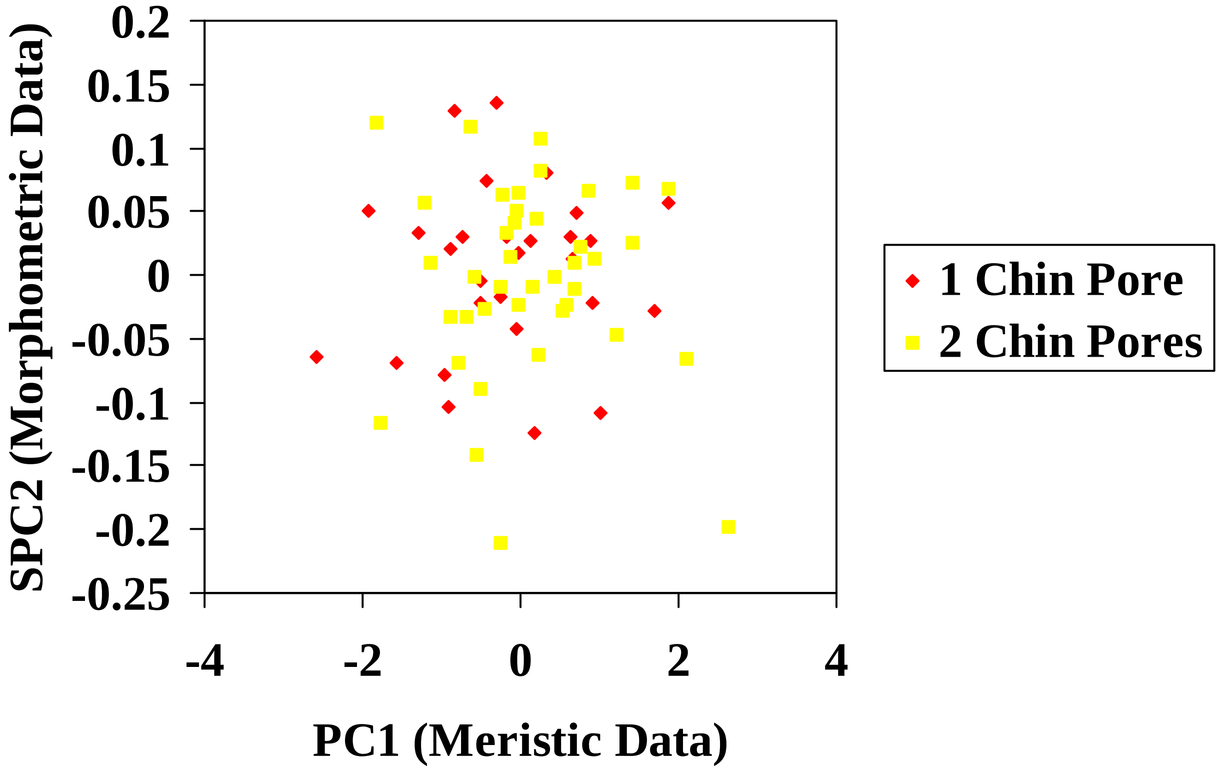

Figure 13. Sheared second principle component (morphometric data) vs first principle component (meristic data) of *Cottus bairdi* populations.

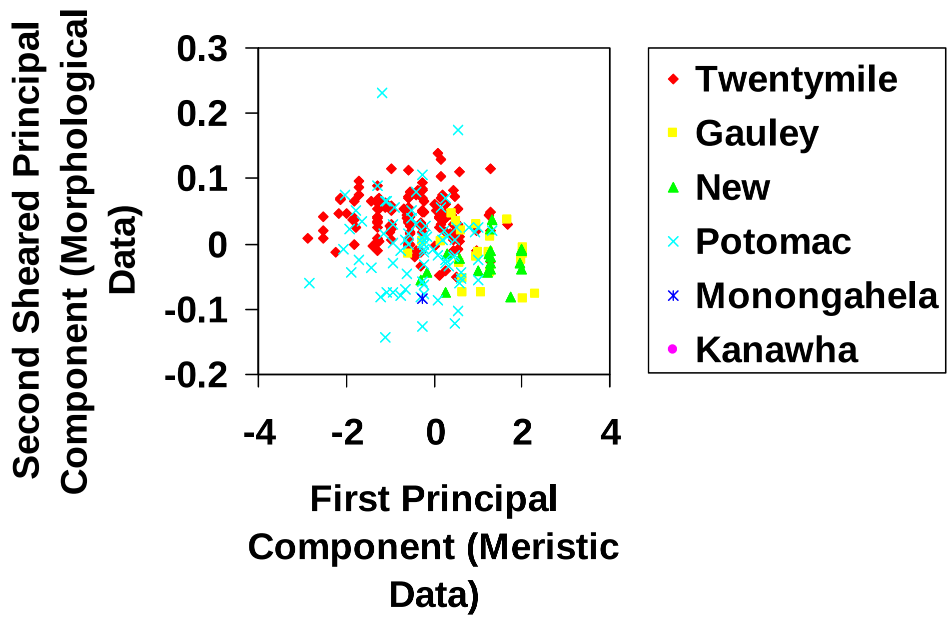

Figure 14. Sheared second principle component (morphometric data) vs first principle component (meristic data) of *Nocomis micropogon* populations.

APPENDIX A: Distribution, life history, and biology information for the 56 species collected in the primary region of MTM/VF coal mining in West Virginia and Kentucky during Fall 1999/Spring 2000 and Fall 2001. Species are listed in phylogenetic order.

Lampetra aepyptera (Abbott), Least Brook Lamprey.
The least broook lamprey superficially resembles the American brook lamprey (*Lampetra appendix*), but the former has fewer than 62 myomeres, and its teeth are poorly developed or missing. The least brok lamprey is found along the Atlantic Slope from North Carolina to Pennsylvania and west of the Appalachian Mountains in the Mississippi River basin from Pennsylvania and Alabama west to Missouri and Arkansas (Rhode and Jenkins 1980). It is widespread in West Virginia and has been collected in the Monongahela, Little Kanawha, Kanawha, Big Sandy, and Guyandotte rivers. We found it in this survey in the Guyandotte River drainage at stations 16, 19, 20, 21, which are all located in the Mud River. In Fall 2001, this lamprey was collected at station 20 of the Mud River and stations 74, 75, 77, and 78 of the Big Ugly. This lamprey is a filter feeding, headwater species, of intermediate tolerance to environmental disturbance.

Oncorhynchus mykiss (Walbaum), Rainbow Trout.
The rainbow trout can be distinguished from the brown trout (*Salmo trutta*) because it has dark spots on its caudal fin, which are absent from the brown trout's; the rainbow trout's body bears a longitudinal reddish stripe, whereas the brown trout's has orange or red spots; the former has 10-12 anal-fin rays, while the brown trout typically has nine. The rainbow trout can be distinguished from the brook trout (*Salvelinus fontinalis*), because the rainbow trout is light with brown or black spots; whereas the brook trout's back has light vermiculations. The rainbow trout's natural distribution encompasses northwest Asia and the Pacific Coast of North America. In West Virginia, it has been introduced statewide. We found it at one station in Spruce Fork (station 44; Kanawha River drainage) in this survey.

Salmo trutta Linnaeus, brown trout.
The absence of spots on the caudal fin of the brown trout distinguishes it from the rainbow trout, which possesses caudal spots. The brown trout can be distinguished from the brook trout (*Salvelinus fontinalis*), because the brown trout is light with brown or black spots; whereas the brook trout's back has light vermiculations. Brown trout are native to Europe and western Asia. In West Virginia, fingerlings and catchable trout have been stocked extensively. We collected three specimens in Toney Fork (station 36) of the Kanawha River drainage. The brown trout was not included in the calculations of species richness and total numbers because although it was collected in Toney Fork, it was taken the stream reach outside of the measured sampling area.

Campostoma anomalum (Rafinesque), Central Stoneroller.
Adult central stonerollers superficially resemble *Nocomis* spp. and juvenile white suckers (*Catostomus commersoni*). The stonerollers can be readily distinguished from all of these by the presence of a cartilaginous plate on their lower lips and their lack of barbels. The central stoneroller is widely distributed over the eastern two-thirds of the United States. It is present from New York south to Alabama and Louisiana, west to the Red River of North and South Dakota, and north to the Upper Mississippi River in Minnesota. In West Virginia, it is

common and often locally abundant in all of the major river systems. We collected it throughout the New, Guyandotte, Kanawha, and Kentucky drainages. This minnow is an herbivore of intermediate tolerance.

Clinostomus funduloides Girard, Rosyside Dace.
The rosyside dace is an elongate minnow that is compressed laterally. It is most easily confused with the redside dace (*Clinostomus elongatus*). The rosyside dace has less than 55 scales along its lateral row, while the redside dace has 60 or more. The rosyside dace occurs in the Atlantic Slope drainages from the Delaware River south to the Savannah River of Georgia. It is also found in the tributaries of the Ohio River in Ohio and West Virgina and tributaries of the Tennessee and Cumberland rivers in Tennessee and Kentucky. In West Virginia, the rosyside dace is found in the Shenandoah River, in the South Fork of the Potomac River, and in the James, Monongahela, New, Guyandotte, and Big Sandy drainages. We collected it at three stations (11, 16, 17) during the 1999/2000 season and two stations (20 and 77) in Fall 2001 in the Guyandotte River drainage. This minnow is a headwater species, an insectivore, a simple lithophil, of intermediate tolerance to environmental disturbances.

Cyprinella galactura (Cope), Whitetail Shiner.
The whitetail shiner superficially resembles other members of *Cyprinella*, but can be spearated from all other species in this genus by the presence of an hourglass-shaped white spot at the base of its caudal fin. The whitetail shiner as a disjunct distribution. It is found in Arkansas and Missouri west of the Mississippi River and in Tennessee and Cumberland rivers east of the Mississippi River. It also occurs in the New River drainage of Virginia and West Virginia, but these populations are believed to be introduced. We collected it at one location (station 54) in Twentymile Creek in the New River drainage. In Fall 2001, we collected it at one station (74) in the Big Ugly watershed (Guyandotte Drainage).

Cyprinella spiloptera (Cope), Spotfin Shiner.
The spotfin shiner can be distinguished form the whitetail shiner because it lacks the hourglass-shaped white spot at the base of its caudal fin. It can be delineated from other *Cyprinella* species, becausethe melanophores on its dorsal fin are concentrated in the posterior 3-4 membranes, whereas these melanophores are found throughout all of the membranes in the other species in this genus. The spotfin shiner usually has eight anal-fin rays, while the others usually have nine. The spotfin shiner occurs from the Potomac River to the Hudson River on the Atlantic Slope, throughout the lower Great Lakes, and in the upper Mississippi Valley south to the Tennessee River drainage in Alabama and the Arkansas River drainage in Oklahoma. In West Virginia, it is found statewide, being absent only from the James River drainage. We collected one specimen at station 45 in Spruce Fork of the Kanawha River drainage. The spotfin shiner is an insectivore with intermediate tolerance to environmental stress.

Cyprinus carpio Linnaeus, Common Carp.
The common carp is a large minnow with a thick, laterally-compressed body and two pairs of barbels on the upper jaws. The common carp is native to temperate Asia and portions of Europe. It is has been introduced to much of North America. In West Virginia, it occurs in

all of the major drainages. We collected one specimen at station 42 in Spruce Fork of the Kanawha River basin. The common carp is an omnivore that is tolerant to environmental stress.

Ericymba buccata Cope, Silverjaw Minnow.
The silverjaw minnow is most easily confused with the sand, mimic, and bigmouth shiners (*Notropis ludibundus, Notropis volucellus,* and *Notropis dorsalis*, respectively). It can be distinguished from all three of these species by virtue of its greatly enlarged suborbital canals, which appear as large, honey-comb-shaped spaces. The silverjaw minnow occurs from the Apalachicola drainage of Florida west to the Pearl River drainage of Mississippi/Louisiana. Further north, it occurs from the Suspuehanna and Potomac rivers west to the Mississippi River drainage in Illinois. It is common throughout the upper Ohio Valley. There is one record from the upper Tennessee River drainage and this possibly represents a remnant population. In West Virginia, the silverjaw minnow is found statewide. We collected it at eight stations in the Guyandotte River drainage, one in the Kanawha River drainage, and at two sites in Kentucky. In Fall 2001, we collected this minnow in two Mud River stations (19, 20), all five Big Ugly stations (74-78), and one Guyandotte station (79). This minnow is considered a pioneering species; it is an insectivore with intermediate tolerance to environmental stress.

Luxilus albeolus (Jordan), White Shiner.
The white shiner is most easily confused with the common shiner, *Luxilus cornutus* and the striped shiner, *Luxilus chrysocephalus*. It can be distinguished from the common shiner by its lack of crowded pre-dorsal scales. The presence of three or four parallel dark bands, which converge at the mid-dorsal line in the striped shiner, are absent in the white shiner. The white shiner is present on the Atlantic slope from the Roanoke River drainage of Virginia south to the Cape Fear River drainage of North Carolina. The white shiner also occurs in the New River drainage of North Carolina, Virginia, and West Virginia, where it was possibly introduced. We collected it at three localities (stations 54, 57, 58) in Twenty Mile Creek of the New River drainage.

Luxilus chrysocephalus (Rafinesque), Striped Shiner.
The striped shiner is most similar to the common shiner and the white shiner. It can be distinguished from the former by virtue of its heavier chin pigmentation and its lack of crowded pre-dorsal scales. It can be distinguished from the white shiner, because the striped shiner has 3-4 parallel dark bands, which converge on the mid-dorsal line. The striped shiner occurs from the lower Great Lakes basin south throughout the Ohio River drainage, south throughout the Mississippi River Valley, and east along the Gulf Coast to the Mobile Bay drainage. In West Virginia, the striped shiner is found in the Potomac drainage and throughout the Ohio River and its tributaries. We collected it at six localities in the Kanawha River drainage, seven localities in the Guyandotte River drainage, two localities in the New River drainages, and at 10 sites in Kentucky. In Fall 2001, we collected this minnow at three Mud River stations (20, 22, 23) and all five Big Ugly stations. This insectivore is a simple lithophil that has intermediate tolerance to environmental stress.

Lythrurus ardens (Cope), Rosefin Shiner.
The rosefin shiner has a dark pigment spot on the base of the first several dorsal-fin rays, and 9-11 anal rays. The rosefin shiner occurs on the Atlantic Slope from the York River of Virginia south to the Neuse River of North Carolina. In the Ohio Valley it occurs in the Tennessee River north to the Scioto River of Ohio, and is also present in the new River of Virginia and West Virginia. We collected it in Clear Fork of the Cumberland River and Big Double Creek in the Kentucky River in Kentucky. The rosefin shiner is an insectivore with intermediate tolerance to environmental stress.

Nocomis micropogon (Cope), River Chub.
The river chub is most easily confused with other species in this genus. The river chub has only one row of pharyngeal teeth, while the hornyhead chub (*Nocomis biguttatus*) has two. The simple S-shaped intestine of the river chub delineates it from the bluehead chub, *Nocomis leptocephalus*, which has a long coiled intestine. The river chub does not inhabit the New River, where the bigmouth chub, *Nocomis paltyrhynchus* occurs. The river chub occurs from the Susquehanna River drainage in New York south to the James River drainage of Virginia and West Virginia. It is also found throughout the lower Great Lakes and the Ohio River basins. In West Virginia, it occurs statewide, being absent only from the New River. We collected one specimen in Island Creek (station 14) of the Guyandotte River drainage, one specimen from Fugate Fork (station 68) of the Kentucky River in Kentucky. This minnow is an insectivore that is intolerant of environmental stress.

Nocomis platyrhynchus Lachner and Jenkins, Bigmouth Chub.
The short S-shaped intestine of the bigmouth chub distinguishes it from the bluehead chub, *Nocomis leptocephalus*, which has a long coiled intestine. It is delineated from all other *Nocomis* species, based on tubercle patterns on the head of breeding males; the bigmouth chub is endemic to the New River system. We collected it at stations 54 and 58 located on Twentymile Creek in the New River drainage. There were some fishes collected in Twentymile Creek that appeared to resemble *Nocomis micropogon*. Not enough males with breeding tubercles were collected to identify these fishes. We did a shape analysis of these specimens and compared them with known populations of *N. micropogon* (Fig. 14). Again, these data were equivocal; hence we identified all specimens collected in Twentymile Creek as *N. platyrhynchus*, but more analyses of these populations are needed.

Notropis ludibundus (Girard), Sand Shiner.
The sand shiner superficially resembles the ghost shiner (*Notropis buchanani*) and the mimic shiner (*Notropis volucellus*). It can be separated from both of these species, because the anal-fin of the sand shiner has only seven rays, while the other two species have eight anal rays. The sand shiner occurs from the Rio Grande River of Texas north through the Mississippi Valley and the lower Great Lakes basin. In West Virginia, the sand shiner occurs throughout the Ohio River drainage. We collected it at three localities in the Guyandotte River drainage and two localities in the Kanawha River basin. In Fall 2001, we collected it in one Mud River station (22) and two Big Ugly stations (74, 75). The sand shiner is an insectivore with intermediate tolerance to environmental stress.

Notropis photogenis (Cope), Silver Shiner.
The silver shiner can be delimited from all other *Notropis* species in the study area because it has nine pelvic-fin rays, and all other *Notropis* species have 8 pelvic-fin rays. The silver shiner is present in the western portion of the Lake Erie basin and the Grand River of Ontario. It is found throughout most of the Ohio River drainage south to the Tennessee river. In West Virginia, the silver shiner is found in all of the major Ohio River tributaries. We collected it at stations 42-45 in the Kanawha River drainage. The silver shiner is an insectivorous lithophil that is intolerant of environmental stress.

Notropis rubellus (Agassiz), Rosyface Shiner.
The rosyface shiner can be delimited from all other *Notropis* species because its insertion of the dorsal fin is posterior to the pelvic-fin insertion. The rosyface shiner occurs from the Great Lakes Basin and upper Mississippi Valley south to the Tennessee and Missouri river drainages. There is an isolated population in the Ouachita River drainage of Arkansas. In West Virginia, it occurs in every major river drainage. The New River population is distinct and will probably be described as a separate species (Mayden, personal comm.). We collected it from five sites in the Kanawha River basin, one site in the Guyandotte River basin, one site in the New River basin, and at four sites in Kentucky. In Fall 2001, we collected it in two Big Ugly stations (74, 75). The rosyface shiner an insectivorous lithophil that is intolerant to environmental stress.

Notropis telescopus (Cope), Telescope Shiner.
The telescope shiner can be recognized by the presence of an irregular scale pattern on the first one or two scale rows. It occurs in the upland areas of the Mississippi Valley from the White River of Arkansas south to the Tennessee River in Alabama and east to the Cumberland River drainage in Virginia. In West Virginia, the telescope shiner is restricted to the Kanawha, and Big Sandy rivers. We collected it at two sites (stations 54 and 58) in Twentymile Creek in the New River drainage.

Notropis volucellus (Cope), Mimic Shiner.
The mimic shiner can be easily confused with the sand and ghost shiners. It can be distinguished from the sand shiner, because it has eight anal-fin rays, while the sand shiner only has seven. Its pelvic fins are shorter than the ghost shiner's and reach the anal-fin origin. We collected the mimic shiner at one station (54) in the New River drainage, 2 stations in the Kanawha River drainage, and at two stations in Kentucky. The mimic shiner is an insectivore that is intolerant to environmental stress.

Phoxinus erythrogaster (Rafinesque), Southern Redbelly Dace.
The southern redbelly dace is most easily confused with the mountain redbelly dace (*Phoxinus oreas*). It can be distinguished from the mountain redbelly dace, because the southern redbelly dace has two parallel lateral stripes along the entire length of its body, whereas the mountain redbelly dace has lateral stripes, which are not parallel and do not extend along the entire length of its body. The southern redbelly dace is widely distributed from southern Minnesota and Wisconsin east ot western Pennsylvania and south to Alabama and northern Arkansas. There are isolated populations in the upper Arkansas River of New Mexico and along the Mississippi River in Mississippi. In West Virginia, the southern

redbelly dace is found in the small headwater streams in the Ohio River drainage. We collected it at station 26 in Buffalo Fork in the Kanawha River drainage and at two localities (stations 61, 63) in Kentucky. This minnow described as an herbivorous headwater species that is a simple lithophil and has an intermediate tolerance to environmental stress.

Pimephales notatus (Rafinesque), Bluntnose Minnow.
The bluntnose minnow can be distinguished from the fathead minnow because the bluntnose minnow has a slimmer body and a complete lateral line. It can be separated from other minnows in West Virginia on the basis of its crowded pre-dorsal scales. The bluntnose minnow is widely distributed throughout the Mississippi Valley and Great Lakes. Atlantic Coast populations occur from Virginia to Quebec. It is found in all of the major drainages of West Virginia, with the exception of the James. We collected it at two localities in the Kanawha River drainage, three in the New River drainage, seven in the Guyandotte, and at nine localities in Kentucky. In Fall 2001, we collected this minnow at three Mud River stations (12, 19, 20), all five Big Ugly stations (74-78), and one Guyandotte station (79). This minnow is an omnivorous pioneering species that is tolerant to environmental stress.

Pimephales promelas Rafinesque, Fathead Minnow.
The fathead minnow can be distinguished from other *Pimephales* species, because an incomplete lateral line and a more robust body. The fathead minnow is distributed throughout most of North America. In West Virginia, it can be found in all of the major drainages. It is used as a bait fish and, as such, has been introduced widely. We collected it in Stanley Fork (station 18) in the Guyandotte River during the 1999/2000 season and at two stations (17 and 18) during the 2001 season. This omnivorous minnow is a pioneering species that is tolerant of environmental stress.

Rhinichthys atratulus (Hermann), Blacknose Dace.
The blacknose dace is most easily confused with the longnose dace (*Rhinichthys cataractae*) from which is differs because the blacknose dace lacks a fleshy snout hanging over its mouth. The blacknose dace occurs from Nova Scotia west throughout the Great Lakes and upper Mississippi River drainages and south to Tennessee, Georgia, and Alabama. In West Virginia, the blacknose dace is found in all of the major river drainages. We collected it at 18 localities in the Guyandotte River drainage, 19 sites in the Kanawha River drainage, eight sites in the New River drainage, and at five stations in Kentucky. During Fall 2001, we collected this minnow at two Mud River stations (19, 20), three Big Ugly stations (76, 77, 78), and all three Guyandotte stations (79, 80, 81). The blacknose dace is described as a generalist, headwater, lithophilous, minnow that is tolerant to environmental stress.

Semotilus atromaculatus (Mitchill), Creek Chub.
The creek chub is a large minnow with a robust body and a broad, stout head. The creek chub occurs throughout much of the United States from Montana and New Mexico east to the Atlantic Coast. In West Virginia, it is found in all of the major drainages. We collected it 17 localities in the Guyandotte River drainage, at 17 localities in the Kanawha River drainage, at 11 localities in the New River drainage, and at 14 localities in Kentucky. During Fall 2001, the creek chub was collected at all stations. The creek chub is a generalist pioneering minnow that is tolerant of environmental stress.

Catostomus commersoni (Lacepede), White Sucker.
The white sucker superficially resembles the longnose sucker (*Catostomus catostomus*). The two can be distinguished form each other because the white sucker has 55-85 lateral-line scales, whereas the longnose sucker has 98-108. The white sucker is found throughout Canada south to New Mexico and Georgia. In West Virginia, it is found in all of the major drainages. We collected it at three stations in the Kanawha River drainage, 10 stations in the Guyandotte, six localities in the New River drainage, and four sites in Kentucky. During Fall 2001, white suckers were collected at four Mud River stations (12, 17, 20, 23), one Big Ugly (77), and one Guyandotte station (79). The white sucker is described as an omnivorous lithophil that is tolerant of environmental stress.

Hypentelium nigricans (LeSueur), Northern Hog Sucker.
The combination of a short dorsal fin (< 18 rays), a complete lateral line, and a head, which is concave between the eyes distinguishes the northern hog sucker from all other suckers in our study. The northern hog sucker occurs throughout the Mississippi River system, the Great Lakes region, and the Atlantic Slope from New York to northern Georgia. In West Virginia, the northern hog sucker occurs in virtually all stream systems. We collected it at eight localities in the Guyandotte River drainage, nine stations in the Kanawha River drainage, 10 sites in the New River drainage, and 10 sites in Kentucky. In Fall 2001, we collected it in two Mud River stations (18, 22), four Big Ugly stations (74, 75, 77, 78), and one Guyandotte station (79). The northern hog sucker is an insectivorous lithophil that is intolerant to environmental stress.

Moxostoma erythrurum (Rafinesque), Golden Redhorse.
The golden redhorse superficially resembles several of the large redhorse suckers (*Moxostoma* spp.) in West Virginia. Its slate-colored tail distinguishes it from both the river redhorse (*Moxostoma carinatum*) and the Ohio shorthead redhorse (*Moxostoma macrolepidotum breviceps*). The northern shorthead redhorse (*Moxostoma macrolepidotum macrolepidotum*), which has a slate-colored tail has a medial bulb on its upper lip that the golden redhorse lackes. The number of lateral-line scales present in the golden redhorse (39-43) separates it from the black redhorse (*Moxostoma duquesnei*), which has 44-47. The golden redhorse is widely distributed throughout the Mississippi River north to the Great Lakes. An isolated population (possibly introduced) is found in the Potomac River. In West Virginia, the golden redhorse occurs in all of the major drainages except the James River. We collected it at three sites in the Guyandotte River drainage, at one site in the Kanawha River drainage, and at one site in Kentucky. During Fall 2001, it was only collected at one station in the Big Ugly watershed (station 74). The golden redhorse is described as an insectivorous lithophil that is moderately tolerant to environmental stress.

Ameiurus melas (Rafinesque), Black Bullhead.
The black bullhead differs from the yellow bullhead (*Ameiurus natalis*) in having brown or black chin barbells and a slightly forked or rectangular caudal fin. It is distinguished from the brown bgullhead (*Ameiurus nebulosus*) because it lacks strongly barbed pectoral fins and usually has fewer anal-fin rays (16-22) than does the brown bullhead (21-24). The black bullhead is native from southern Canada, Montana, and northern Mexico east to the Saint Lawrence River, the Appalachian Mountains, and Alabama. In West Virginia, it is found in

the main channel and greater Ohio River. It occupies both lotic and lentic areas throughout its range. It prefers silty water and is not able to populate the cool, clear waters inhabited by brown and yellow bullheads. In this survey, we collected one specimen at one station in the Mud River watershed (station 17) during Fall 2001.

Ameiurus natalis (LeSueur), Yellow Bullhead.
The yellow bullhead has yellow/white chin barbels, while both the brown bullhead (*Ameiurus nebulosus*) and the black bullhead (*Ameiurus melas*) have brown to black chin barbels. The yellow bullhead's caudal fin in slightly rounded, while the brown bullhead's caudal fin has a straight posterior margin. The yellow bullhead is indigenous to central and eastern North America. In West Virginia, it occurs in both the Ohio and Atlantic Slope drainages. We collected it at three localities in the Guyandotte River drainage and at one locality in Kentucky. In Fall 2001, we collected it at two Mud River stations (22, 23). The yellow bullhead is described as a tolerant insectivore.

Ameiurus nebulosus (LeSueur), Brown Bullhead.
The brown bullhead can be distinguished from the yellow bullhead (*Ameiurus natalis*) because the brown bullhead has brown or black barbels, wheras the yellow bullhead has white/hellow barbells. Strongly-barbed pectoral spines and 21-24 anal-fin rays distinguish the brown bullhead from the black bullhead (*Ameiurus melas*), which has 16-20 anal-fin rays and weakly-barbed pectoral spines. The brown bullhead is native to eastern North America, but it has been widely introduced outside its native range. In West Virginia, it is found in the Potomac and Ohio River drainages. It occurs in both lentic and lotic habitats, in associated with moderate amounts of aquatic vegetation, and prefers clearer, cooler water than do other *Ameiurus* species. We collected one specimen at one station in the Mud River watershed (station 18) in Fall 2001.

Noturus miurus Jordan, Brindled Madtom.
The brindled madtom can be distinguished from other *Noturus* species, because it posseses a curved pectoral spine with anterior and posterior serrae, and it has three bold, distinct blotches on its dorsal surface. The brindled madtom is native to the portions of the Gulf Slope, including the Mississippi River through the Ohio River basin and throughout the lower parts of Lake Erie and Lake Ontario drainages. In West Virginia, it occurs throughout the Ohio River basin. We collected one specimen at one site (station 22 in Spring 2000) in the Mud River during the 1999/2000 season and four specimens at one site in the Big Ugly (station 74) in Fall 2001 (both in Guyandotte River drainage). The brindled madtom is an intolerant benthic insectivore.

Labidesthes sicculus (Cope), Brook Silverside.
The brook silverside superficially resembles a slender minnow. It can be distinguished, however, by its beak-like snout and the presence of two clearly separted dorsal fins. The brook silverside is widely distributed throughout the Mississippi Valley, including all of the Ohio River drainage. It is also present throughout the lower Great Lakes basin, the Atlantic Slope from South Carolina to Florida, and west along the Gulf Coast to Texas. In West Virginia it is found throughout the Ohio River basin and is most common in the Little Kanawha River, the West Fork of the Monongahela River, and in Twelvepole Creek. We

found the brook silverside at only one station in the Mud River watershed (station 20) during Fall 2001. Brook silversides prefer pool areas of streams and quiet areas of lakes with an abundance of aquatic vegetation.

Cottus bairdi Girard, Mottled Sculpin.
The mottled sculpin can be distinguished from the Potomac sculpin (*Cottus girardi*) and the banded sculpin (*Cottus carolinae*) because the mottled sculpin's chin is uniformaly colored, whereas those of the latter two species have distinct blotches. The mottled sculpin can be distinguished from the slimy sculpin (*Cottus cognatus*) because it has 4 pelvic-fin rays, as opposed to three. The mottled sculpin usually has two medial chin pores. In several of the populations that we sampled, we found an almost equal number of mottled sculpins with either one or two chin pores. The mottled sculpin's native range is discontinuous throughout North America with populations occurring from Canada south to Georgia, Alabama, and New Mexico. In West Virginia, it is found in all of the major drainages. The mottled sculpin is an intolerant, benthic, headwater insectivore.

Ambloplites rupestris (Rafinesque), Rock Bass.
The rock bass superficially resembles crappies (*Pomoxis* spp.), warmouths (*Lepomis gulosus*), and green sunfish (*Lepomis cyanellus*). It differs from all *Lepomis* species in having five to eight anal spines, instead of three. The rock bass has 10-13 dorsal-fin spines, whereas *Pomoxis* species have six to eight. The rock bass occurs from northern Georgia north to southern Ontario and west to the western tributaries of the Mississippi River. In West Virginia, it occurs in all of the major drainages. We collected it in the Guyandotte, Kanawha, New, and Kentucky drainages. During Fall 2001, we collected it in one Mud River site (23) and three Big Ugly sites (74, 75, 78). The rock bass is a piscivore that exhibits intermediate tolerance to environmental stresses.

Lepomis auritus (Linnaeus), Redbreast Sunfish.
The redbreast sunfish superficially resembles the bluegill (*Lepomis macrochirus*), because these are the only two *Lepomis* species that have a black margin to its opercular spot. It differs from the bluegill, because the redbreast sunfish lacks the black spot, which is present at the posterior base of the bluegill's dorsal fin. The redbreast sunfish is native to the Atlantic Slope from southern Canada to central Florida, and west to the Apalachicola River. It has been widely introduced outside of its native range. We collected it at only two sites in the Cumberland River drainage in Kentucky. The redbreast sunfish is described as an insectivore with intermediate tolerance to environmental stresses.

Lepomis cyanellus Rafinesque, Green Sunfish.
The green sunfish resembles the warmouth (*Lepomis gulosus*), but unlike the warmouth's tongue, the tongue of the green sunfish bears no teeth. The green sunfish can be distinguished from all other *Lepomis* species because the green sunfish possesses a large mouth, the maxilla of which, extends to or beyond the middle of the eye. We collected it in all of the major drainages that we sampled. In Fall 2001, the green sunfish was caught at seven of the Mud River stations, but it was not caught at any of the Big Ugly reference stations. The green sunfish is described as a pioneering insectivore that is tolerant to environmental stresses.

<u>*Lepomis gibbosus* (Linnaeus), Pumpkinseed</u>.
The pumpkinseed can be distinguished from the longear sunfish (*Lepomis megalotis*) and the redear sunfish (*Lepomis microlophus*) because the pumpkinseed's opercle is stiff to its bony margin. It differs from other *Lepomis* species because its gill rakers are short and thick. The pumpkinseed is native to the Atlantic Slope drainages from Canada to northern Georgia, and west throughout the Great Lakes drainages and upper Mississippi River basin. In West Virginia, it is found in most of the major drainages. It appears to prefer cooler water than do most of the other *Lepomis* species. We collected it in one site of the Big Ugly watershed (station 75) during Fall 2001.

<u>*Lepomis macrochirus* Rafinesque, Bluegill</u>.
Only the bluegill and the redbreast sunfish have an opercular spot that is black to its margin. The black spot at the posterior base of the bluegill's dorsal fin distinguishes it from the redbreast sunfish. The bluegill is native to eastern and central North America from Virginia to Florida, west to Texas and northern Mexico, and north to western Minnesota and western New York. It has been introduced throughout North America, Europe, and South Africa. The bluegill is widely distributed throughout West Virginia and has been collected in all of the major drainages. We collected it in the Guyandotte and Kanawha rivers and at the sites in Kentucky. In Fall 2001, we collected it at three Mud River sites and one Big Ugly site. The bluegill is an insectivore that demonstrates intermediate tolerance to environmental stresses.

<u>*Lepomis megalotis* (Rafinesque), Longear Sunfish</u>.
The longear sunfish resembles the pumpkinseed sunfish (*Lepomis gibbosus*) and the redear sunfish (*Lepomis microlophus*). It differs from the pumpkinseed sunfish because the longear sunfish's opercle is flexible at its margin, whereas the pumpkinseed's is stiff to its bony margin. The longear sunfish as short pectoral fins, while the redear's are long, extending beyond the eye when laid forward. The longear sunfish is widely distributed throughout the Mississippi River basin and long the Gulf Slope from western Florida to Texas; it is patchily distributed in the Great Lakes drainages. The longear sunfish is distributed throughout West Virginia, being only absent from the James River. We collected it in the Guyandotte and Kentucky river drainages. During Fall 2001, we collected it at two Mud River sites and four Big Ugly sites. The longear sunfish is described as an insectivore with intermediate tolerance to environmental stresses.

<u>*Micropterus dolomieu* Lacepede, Smallmouth Bass</u>.
The lack of a dark mid-lateral band distinguishes the smallmouth bass from both the spotted bass (*Micropterus punctulatus*) and the largemouth bass (*Micropterus salmoides*). The smallmouth bass is native to the Great Lakes drainages and the Mississippi River basin. It has been introduced throughout the world. In West Virginia, it occurs in all of the major drainages. We caught it in the Kanawha, Guyandotte, and Kentucky drainages. During Fall 2001, we only caught it at four of the Big Ugly reference sites. Smallmouth bass are piscivores with intermediate tolerance to environmental stresses.

Micropterus punctulatus (Ranfinesque), Spotted Bass.
The spotted bass can be distinguished from the smallmouth bass (*Micropterus dolomieu*) because of its dark mid-lateral band. Its unbranched pyloric caeca and the tricolored tails of juveniles distinguish it from the largemouth bass (*Micropterus salmoides*). The spotted bass is indigenous to the central Misissippi River basin from northern Missouri to western Pennsylvania, south to Mississippi and Louisana, and along the Gulf Coast from Texas to western Florida. It has been introduced elsewhere. In West Virginia, the spotted bass is distributed widely throughout the Ohio River drainages. We captured it in the Guyandotte River in West Virginia and the Cumberland River drainages in Kentucky. In Fall 2001, we caught it in two stations in the Mud River and two stations in the Big Ugly. Spotted bass are piscivores with intermediate tolerance to environmental stresses.

Micropterus salmoides (Lacepede), Largemouth Bass.
Two strains of largemouth bass are recognized in North America, a northern strain and a Florida strain. The former is native to West Virginia; members of the latter probably now occur within the state. The largemouth bass can be distinguished from other *Micropterus* species in West Virginia and Kentucky on the basis of its large mouth, the maxilla of which extends behind the eye in adults. The largemouth bass is indigenous to the Mississippi River basin from northeastern Mexico to Florida, and north to the Great Lakes drainages of southern Canada. Its native range on the Atlnatic Slope was restricted to southern Florida north to southern or central South Carolina. It has been introduced throughout the world. In West Virginia, the largemouth bass occurs in all of the major drainages. We collected it in the Guyandotte and Kanawha river drainages. Largemouth bass are piscivores with intermediate tolerance to environmental stresses.

Etheostoma baileyi Page and Burr, Emerald Darter.
The emerald darter is the only member of the subgenus *Ulocentra*, which occurs in the Cumberland River system upstream of the Big South Fork (Etnier and Starnes 1993). The emerald darter is native to the upper Kentucky River and Cumberland river drainages of Kentucky and Tennessee above Cumberland Falls, and in the Rockcastle and Big South Fork systems, below Cumberland Falls (Etnier and Starnes 1993). We collected it throughout the stations sampled in Kentucky. The emerald darter is a benthic lithophilous insectivore that is intolerant of environmental stresses.

Etheostoma blennioides Rafinesque, Greenside Darter.
The greenside darter superficially resembles the banded darter (*Etheostoma zonale*). The greenside darter has a blunt snout and lacks a frenum, unlike the banded darter. The greenside darter is found from Kansas and Oklahoma east to New York, and from Ontario south to Alabama, Georgia, and Arkansas. In West Vriginia, the greenside darter is found in all of the major drainages except for the James River. We collected it throughout all of the major drainages that we sampled. During Fall 2001, we collected it at two sites in the Mud River and three sites in the Big Ugly. The greenside darter is a benthic lithophious insectivore with intermediate tolerance to environmental stresses.

Etheostoma caeruleum Storer, Rainbow Darter.
The rainbow darter superficially resembles the orangethroat darter (*Etheostoma spectabile*). The rainbow darter has red coloration in its anal fin and a complete infraorbital canal, both of which the oragnethroat darter lacks. The rainbow darter occurs primarily in the Great Lakes and Mississippi River drainages, from Minnesota east to New York and south to Arkansas, Alabama, and Georgia. Esmond and Stauffer (1983) reported it from the upper Potomac River in West Virginia. Elsewhere in West Virginia, it is found in the tributaries of thegreater Ohio River. There are no records of this species from the Little Kanawha River. We found it in all of the major drainages that we sampled. In Fall 2001, we found it in both the Mud River and Big Ugly. The rainbow darter is described as a benthic lithophilous insectivore. Barbour et al. (1999) describe this species as having intermediate tolerance to environmental stresses, while Messinger and Chambers (2001) describe it as being intolerant.

Etheostoma flabellare Rafinesque, Fantail Darter.
The fantail darter is the only member of the subgenus *Catonotus* in West Virginia. In Kentucky, it superficially resembles the stripetail darter (*Etheostoma kennicotti*), which had a prominent black submarginal band in the first dorsal fin that the fantail darter lacks (Etnier and Starnes 1993). We collected it in all of the major drainages that we sampled. In Fall 2001, we found it at two Mud River stations and all five Big Ugly stations. This darter is described as a headwater benthic insectivore with intermediate tolerance to environmental stresses.

Etheostoma kennicotti (Putnam), Stripetail darter.
The stripetail darter does not occur in West Virginia. In Kentucky, it superficially resembles the fantail darter (*Etheostoma flabellare*). The presence of a dark submarginal band on the first dorsal fin of the stripetail darter distinguishes it from the fantail darter. It is native throughout much of the Tennessee River drainage, above and below the Cumberland Falls in the Cumberland drainage, and in the Green River drainage of the Ohio River (Etnier and Starnes 1993). We collected it at two sites in the Cumberland River drainage. This darter is described as a benthic headwater insectivore with intermediate tolerance of environmental stresses.

Etheostoma nigrum Rafinesque, Johnny Darter.
The johnny darter resembles both the longfin darter (*Etheostoma longimanum*) and the tessellated darter (*Etheostoma olmstedi*). The johnny darter has one anal-fin spine, while the longfin darter has two. The tessellated darter has an incomplete infraorbital canal and the johnny darter has a complete infraorbital canal. The johnny darter is occurs as far west as Colorado and as far south as Alabama. Although it is mostly restricted to the Mississippi Valley drainages, it does occur in the Atlantic Slope drainages in Canada, Virginia, and North Carolina. In West Virginia, the johnny darter is widely distributed throughout the Ohio River drainages. We collected it in all of the major drainages we sampled. In Fall 2001, we collected it at three Mud River stations and all five Big Ugly stations. The johnny darter is described as a benthic pioneering insectivore with intermediate tolerance to environmental stresses.

Etheostoma sagitta (Jordan and Swain), Arrow Darter.
The arrow darter is distinguished by its pointed snout and the presence of 9-11 dorsal-fin spines. It is native to the Cumberland River drainage and tributaries of the upper Kentucky River system (Etnier and Starnes 1993). We collected it at two localities in Kentucky. The arrow darter is a benthic headwater insectivore.

Etheostoma variatum Kirtland, Variegate Darter.
The variegate darter superficially resembles the candy darter (*Etheostoma osburni*). The variegate darter has four dark saddles, whereas the candy darter as between 5-6. The variegate darter is endemic to the Ohio River drainage. In West Virginia, it is widely distributed throughout this drainage, being absent only from the Kanawha River system above Kanawha Falls (New River). We collected it in the Kanawha River drainages and in Kentucky. In Fall 2001, we collected it at three sites in the Big Ugly watershed. The variegate darter is a benthic lithophilous insectivore that is intolerant of environmental stresses.

Etheostoma zonale (Cope), Banded Darter.
The banded darter superficially resemble the greenside darter (*Etheostoma blennioides*). The banded darter has a frenum, which is lacking in the greenside darter. The banded darter is widely distributed and common throughout the Mississippi River basin from Kansa and Tennessee, north to Minnesota and New York. In West Virginia, the banded darter is found throughout most of the Ohio River drainage, with the exception of the Tygart Valley River and New River drainages. We collected it in the Kanawha and Guyandotte river drainages. During Fall 2001, we collected it at one Mud River station (22) and two Big Ugly stations (74, 75). This darter is a benthic lithophilous insectivore that is intolerant of environmental stresses.

Percina caprodes (Rafinesque), Logperch.
The logperch is distinguished by its subterminal mouth and fleshy conical snout. It is widely distributed throughout the Ohio River basin in central United States, the White River system in the Ozak Mountains, the Red Rvier system in the Ouachita Mountains, the Atchafalaya River system, the upper Mississippi River basin, the Great Lakes, the Hudson Bay drainages, and south along the central Atlantic Coastal Plain rivers. In West Virginia, the logperch is widely distributed throughout the greater Ohio River drainage. We collected it only in the Guyandotte River drainage during both sampling periods. This benthic lithophilous insectivore exhibits intermediate tolerance to environmental stresses.

Percina maculata (Girard), Blackside Darter.
The blackside darter (subgenus *Alvordius*) resembles the Appalachia darter (*Percina gymnocephala*), and the shield darter (*Percina peltata*). The blackside darter lacks the shield darters characteristic chin bar. The Appalachia darter is endemic to New River. The blackdarter is widely distributed throughout the Mississippi River basin, along the Gulf Slope from Louisiana to Alabaama and in the Great Lakes drainages. In West Virginia, it occurs throughout the greater Ohio River, excluding the New River. We collected it in the Guyandotte River in West Virginia and at several sites in Kentucky. During Fall 2001, we

collected it only at four stations of the Big Ugly watershed. This benthic lithophilous insectivore exhibits intermediate tolerance to environmental stresses.

Percina stictogaster, Frecklebelly Darter.

The frecklebelly darter is an undescribed *Percinia* species from the upper Kentucky and Green river drainages in eastern and central Kentucky and north central Tennessee (Page and Burr 1991). We collected it at two localities in Kentucky. The frecklebelly darter is described as a benthic lithophilous insectivore.

APPENDIX B: Tables of catch composition for each collection by drainage basin (Table 1B = Guyandotte River Drainage (Mud River and Island Creek watersheds), Table 2B = Kanawha River Drainage (Spruce Fork and Clear Fork watersheds), Table 3B = New River Drainage (Twentymile Creek watershed), Table 4B = Cumberland and Kentucky River Drainages) during Fall 1999 and Spring 2000.

Table 1B. Total number caught (Number), total biomass (g), biomass per square meter (g/sq.m.), population estimate (based on 3-pass depletion), and the associated upper 95% confidence limit on the estimate (Upper CL) by species for fish collections completed in the Guyandotte River Drainage (Mud River and Island Creek watersheds), West Virginia during Fall 1999 and Spring 2000. NA in the Estimate column indicates samples where an estimate could not be calculated due to too few fish being caught, an irregular depletion pattern, or all fish being caught in the first pass.

Station # 1 **Collection #:** JRS-99-67 **EPA #:** MT-57B **EIS Class:** 2 **Stream Order:** 1

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
No Fish Caught					

Station # 2 **Collection #:** JRS-99-69 **EPA #:** NA **EIS Class:** 0 **Stream Order:** 1

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
No Fish Caught					

Station # 3 **Collection #:** JRS-00-61 **EPA #:** MT-58 **EIS Class:** 2 **Stream Order:** 1

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	12	31.7	0.12	12	12.2

Station # 4 **Collection #:** JRS-00-62 **EPA #:** MT-52 **EIS Class:** 2 **Stream Order:** 1

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	14	45.5	0.27	14	14.3

Station # 5 **Collection #:** JRS-00-67 **EPA #:** MT-13 **EIS Class:** 0 **Stream Order:** 1

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	1	0.1	0.00	NA	
Semotilus atromaculatus	12	95.7	1.59	NA	

Station # 6F **Collection #:**JRS-99-68 **EPA #:** MT-60 **EIS Class:** 2 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	41	126.6	0.39	41	42.5
Semotilus atromaculatus	18	408.5	1.27	18	20.1

Station # 6S **Collection #:**JRS-00-50 **EPA #:** MT-60 **EIS Class:** 2 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	22	76.8	0.31	NA	
Semotilus atromaculatus	3	10.3	0.04	NA	

** Only 1 pass completed – repeat of collection made in Fall 1999.

Station # 7 **Collection #:** JRS-00-52 **EPA #:** MT-18 **EIS Class:** 2 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	2	2.2	0.01	NA	
Semotilus atromaculatus	7	48.7	0.22	7	8.4

Station # 8 **Collection #:** JRS-00-59 **EPA #:** MT-50 **EIS Class:** 0 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	15	20.7	0.11	19	32.4
Semotilus atromaculatus	29	52.6	0.27	30	33.5

Station # 9 **Collection #:** JRS-00-60 **EPA #:** MT-59 **EIS Class:** 2 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	12	77.3	0.21	12	14.1

Station # 10 **Collection #:** JRS-00-64 **EPA #:** MT-02 **EIS Class:** 0 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	3	1.5	0.01	NA	

Station # 11 **Collection #:** JRS-00-65 **EPA #:** MT-03 **EIS Class:** 0 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	3	11.4	0.04	NA	
Catostomus commersoni	1	11.3	0.04	NA	
Clinostomus funduloides	2	10.4	0.04	NA	
Etheostoma caeruleum	2	2.7	0.01	NA	
Etheostoma nigrum	2	2.8	0.01	NA	
Hypentelium nigricans	2	31.4	0.11	NA	
Lepomis cyanellus	3	10.4	0.04	NA	
Rhinichthys atratulus	1	1.2	0.00	NA	
Semotilus atromaculatus	11	90.1	0.31	NA	

Station # 12 **Collection #:** JRS-00-68 **EPA #:** MT-14 **EIS Class:** 2 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	1	114.0	0.68	NA	
Campostoma anomalum	11	40.9	0.25	16	36.8
Catostomus commersoni	8	609.5	3.65	9	15
Ericymba buccata	2	3.8	0.02	NA	
Etheostoma caeruleum	24	15.8	0.09	27	34.8
Etheostoma flabellare	2	1.1	0.01	NA	
Etheostoma nigrum	4	2.2	0.01	4	5.7
Lepomis cyanellus	53	260.6	1.56	73	104.6
Luxilus chrysocephalus	4	7.3	0.04	4	5.7
Pimephales notatus	2	7.3	0.04	2	6.8
Rhinichthys atratulus	1	0.9	0.01	NA	
Semotilus atromaculatus	45	626.0	3.75	45	46.5

Station # 13 **Collection #:** JRS-00-69 **EPA #:** MT-51 **EIS Class:** 0 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	1	3.1	0.01	NA	
Semotilus atromaculatus	5	41.8	0.15	NA	

Station # 14 **Collection #:** JRS-00-91 **EPA #:** NA **EIS Class:** 3 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	198	1,538.3	1.10	198	199.82
Catostomus commersoni	58	646.1	0.46	58	58.26
Ericymba buccata	171	369.1	0.26	209	240.2
Etheostoma blennioides	43	141.3	0.10	43	43.3
Etheostoma caeruleum	290	388.2	0.28	312	327.7
Hypentelium nigricans	46	2,207.6	1.58	46	47.153
Lepomis cyanellus	1	22.2	0.02	NA	
Luxilus chrysocephalus	1	14.8	0.01	NA	
Micropterus salmoides	2	22.1	0.02	NA	
Notropis ludibundus	360	814.9	0.58	378	390.7
Pimephales notatus	352	765.3	0.55	367	378.3
Rhinichthys atratulus	629	1,931.2	1.38	NA	
Semotilus atromaculatus	185	5,911.0	4.24	186	188.9

Station # 15 **Collection #:** JRS-99-70 **EPA #:** MT-55 **EIS Class:** 3 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	10	176.5	0.46	10	11.4
Catostomus commersoni	15	71.0	0.19	17	24.1
Ericymba buccata	7	13.7	0.04	7	7.8
Etheostoma caeruleum	9	14.7	0.04	9	10.1
Hypentelium nigricans	35	278.4	0.73	36	39.4
Rhinichthys atratulus	231	492.0	1.29	252	268.3
Semotilus atromaculatus	73	1,177.9	3.10	84	98.4

Station # 16 **Collection #:** JRS-00-53 **EPA #:** MT-01 **EIS Class:** 4 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	64	189.3	0.49	64	65.31
Catostomus commersoni	28	7,422.1	19.36	28	28.8
Clinostomus funduloides	41	117.6	0.31	41	41.9
Ericymba buccata	17	33.1	0.09	17	17.8
Etheostoma caeruleum	8	10.0	0.03	8	9.8
Etheostoma flabellare	15	28.7	0.07	19	32.3
Etheostoma nigrum	9	8.8	0.02	9	10.1
Lampetra aepyptera	10	55.9	0.15	NA	
Lepomis cyanellus	8	152.3	0.40	NA	
Lepomis megalotis	1	24.4	0.06	NA	
Luxilus chrysocephalus	21	77.5	0.20	21	23.4
Moxostoma erythrurum	2	1,251.9	3.26	NA	
Pimephales notatus	15	27.0	0.07	15	15.9
Rhinichthys atratulus	77	115.4	0.30	77	78.1
Semotilus atromaculatus	122	430.7	1.12	125	130.1

Station # 17 **Collection #:** JRS-00-54 **EPA #:** NA **EIS Class:** 2 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	24	81.6	0.38	25	28.8
Clinostomus funduloides	1	9.8	0.05	NA	
Etheostoma blennioides	6	24.4	0.11	6	7.7
Etheostoma caeruleum	6	12.1	0.06	6	7.71
Lepomis cyanellus	31	164.6	0.76	31	49.6
Rhinichthys atratulus	1	2.4	0.01	NA	
Semotilus atromaculatus	13	129.2	0.60	13	13.2

Station # 18 **Collection #:** JRS-00-55 **EPA #:** MT-15 **EIS Class:** 2 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	7	32.0	0.19	7	7.3
Catostomus commersoni	1	9.4	0.05	NA	
Lepomis cyanellus	16	158.2	0.92	18	25.1
Pimephales promelas	2	4.7	0.03	NA	
Rhinichthys atratulus	1	2.1	0.01	NA	
Semotilus atromaculatus	11	111.8	0.65	NA	

Station # 19 **Collection #:** JRS-00-57 **EPA #:** MT-07 **EIS Class:** 3 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	36	107.0	0.20	37	40.9
Catostomus commersoni	1	209.9	0.39	NA	
Etheostoma blennioides	3	6.5	0.01	NA	
Etheostoma caeruleum	82	66.4	0.12	85	90.3
Etheostoma flabellare	24	35.0	0.07	26	31.9
Etheostoma nigrum	65	49.9	0.09	124	230.3
Etheostoma zonale	2	1.8	0.00	NA	
Hypentelium nigricans	7	285.4	0.53	NA	
Lampetra aepyptera	1	2.7	0.01	NA	
Lepomis cyanellus	30	132.9	0.25	NA	
Luxilus chrysocephalus	11	19.1	0.04	14	26.2
Pimephales notatus	13	19.3	0.04	14	19.3
Semotilus atromaculatus	16	83.9	0.16	17	21.2

Station # 20 **Collection #:** JRS-00-58 **EPA #:** MT-05 **EIS Class:** 3 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	2	289.3	0.50	NA	
Campostoma anomalum	74	195.4	0.33	76	80.5
Catostomus commersoni	57	13,284.9	22.75	57	57.0
Ericymba buccata	26	79.1	0.14	NA	
Etheostoma blennioides	2	2.3	0.00	NA	
Etheostoma caeruleum	9	5.4	0.01	9	11.8
Etheostoma flabellare	15	35.7	0.06	15	17.5
Etheostoma nigrum	36	40.3	0.07	43	56.4
Etheostoma zonale	6	6.0	0.01	6	6.9
Hypentelium nigricans	1	86.3	0.15	NA	
Lampetra aepyptera	2	9.8	0.02	NA	
Lepomis cyanellus	24	143.7	0.25	31	47.9
Lepomis macrochirus	1	0.5	0.00	NA	
Lepomis megalotis	1	7.1	0.01	NA	
Luxilus chrysocephalus	45	298.2	0.51	53	66.6
Micropterus punctulatus	1	2.3	0.00	NA	
Moxostoma erythrurum	12	5,519.1	9.45	NA	
Percina caprodes	2	9.6	0.02	NA	
Pimephales notatus	16	79.3	0.14	16	17.2
Semotilus atromaculatus	26	324.5	0.56	26	27.9

Station # 21 **Collection #:** JRS-00-66 **EPA #:** MT-04 **EIS Class:** 4 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	34	135.4	0.33	34	34.9
Catostomus commersoni	3	127.3	0.31	NA	
Ericymba buccata	1	2.7	0.01	NA	
Etheostoma caeruleum	4	5.0	0.01	4	5.7
Etheostoma flabellare	2	3.9	0.01	NA	
Etheostoma nigrum	3	3.1	0.01	3	4.1
Hypentelium nigricans	4	366.5	0.90	NA	
Lampetra aepyptera	1	4.2	0.01	NA	
Lepomis cyanellus	12	75.7	0.19	12	13.2
Lepomis macrochirus	1	1.0	0.00	NA	
Luxilus chrysocephalus	18	254.4	0.62	18	18.1
Pimephales notatus	2	6.4	0.02	NA	
Rhinichthys atratulus	1	1.5	0.00	NA	
Semotilus atromaculatus	29	164.4	0.40	29	29.4

Station # 22F **Collection #:** JRS-99-76 **EPA #:** MT-23 **EIS Class:** 3 **Stream Order:**4

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ameiurus natalis	1	45.6	0.08	NA	
Campostoma anomalum	145	383.6	0.67	149	154.7
Catostomus commersoni	5	22.7	0.04	NA	
Ericymba buccata	5	9.1	0.02	5	5.5
Etheostoma blennioides	37	61.5	0.11	37	38.8
Etheostoma caeruleum	114	64.9	0.11	124	135.3
Etheostoma nigrum	5	3.8	0.01	5	5.5
Etheostoma zonale	58	47.2	0.08	67	80.5
Hypentelium nigricans	9	148.7	0.26	9	10.6
Lepomis cyanellus	60	463.8	0.81	69	82.4
Lepomis macrochirus	3	12.8	0.02	NA	
Lepomis megalotis	1	33.2	0.06	NA	
Luxilus chrysocephalus	3	4.1	0.01	NA	
Micropterus punctulatus	1	101.0	0.18	NA	
Micropterus salmoides	1	15.4	0.03	NA	
Notropis ludibundus	21	24.5	0.04	27	42.8
Notropis photogenis	1	2.6	0.00	NA	
Notropis rubellus	4	6.5	0.01	4	4.6
Noturus miurus	1	0.0	0.00	NA	
Semotilus atromaculatus	36	202.2	0.35	36	37.1

Station # 22S **Collection #:** JRS-00-51 **EPA #:** MT-23 **EIS Class:** 3 **Stream Order:** 4

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	1	152.9	0.23	NA	
Ameiurus natalis	1	75.6	0.11	NA	
Campostoma anomalum	66	433.9	0.65	NA	
Catostomus commersoni	4	26.1	0.04	NA	
Ericymba buccata	28	58.7	0.09	NA	
Etheostoma blennioides	20	39.2	0.06	NA	
Etheostoma caeruleum	28	15.9	0.02	NA	
Etheostoma nigrum	1	1.0	0.00	NA	
Etheostoma zonale	16	13.2	0.02	NA	
Hypentelium nigricans	20	194.9	0.29	NA	
Lepomis cyanellus	16	128.9	0.19	NA	
Lepomis macrochirus	1	0.7	0.00	NA	
Luxilus chrysocephalus	27	152.7	0.23	40	71
Moxostoma erythrurum	1	5.4	0.01	NA	
Notropis ludibundus	62	86.7	0.13	NA	
Notropis rubellus	3	6.3	0.01	NA	
Percina caprodes	3	15.6	0.02	NA	
Percina maculata	1	1.8	0.00	NA	
Pimephales notatus	5	23.8	0.04	NA	
Semotilus atromaculatus	9	40.7	0.06	NA	

Station # 23 **Collection #:** JRS-00-56 **EPA #:**MT-17 **EIS Class:** 3 **Stream Order:** 4

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ameiurus natalis	1	81.4	0.16	NA	
Semotilus atromaculatus	9	9.2	0.02	NA	
Rhinichthys atratulus	3	1.3	0.00	NA	
Pimephales notatus	23	122.6	0.23	NA	
Percina caprodes	2	5.9	0.01	NA	
Notropis ludibundus	12	14.6	0.03	NA	
Moxostoma erythrurum	2	405.0	0.77	NA	
Micropterus salmoides	2	249.2	0.48	NA	
Lepomis megalotis	4	106.3	0.20	4	7.0
Ericymba buccata	6	9.2	0.02	NA	
Etheostoma blennioides	14	27.5	0.05	14	14.3
Etheostoma caeruleum	8	9.7	0.02	8	8.6
Etheostoma nigrum	6	6.7	0.01	6	9.5
Etheostoma zonale	4	3.5	0.01	NA	
Lepomis macrochirus	3	15.2	0.03	NA	
Lepomis cyanellus	83	541.8	1.03	105	131.4
Ambloplites rupestris	2	180.3	0.34	NA	
Hypentelium nigricans	8	164.8	0.31	8	8.7
Luxilus chrysocephalus	7	100.4	0.19	NA	

Table 2B. Total number caught (Number), total biomass (g), biomass per square meter (g/sq.m.), population estimate (based on 3-pass depletion), and the associated upper 95% confidence limit on the estimate (Upper CL) by species for fish collections completed in the Kanawha River Drainage (Spruce Fork and Clear Fork watersheds), West Virginia during Fall 1999 and Spring 2000. NA in the Estimate column indicates samples where an estimate could not be calculated due to too few fish being caught, an irregular depletion pattern, or all fish being caught in the first pass.

Station # 24 **Collection #:** JRS-00-92 **EPA #:** MT-42 **EIS Class:** 0 **Stream Order:** 1

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
No Fish Caught					

Station # 25 **Collection #:** JRS-99-71 **EPA #:** MT-25B **EIS Class:** 2 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Lepomis cyanellus	1	2.8	0.01	NA	
Rhinichthys atratulus	7	16.3	0.05	7	7.8
Semotilus atromaculatus	59	478.1	1.45	59	60.6

Station # 26 **Collection #:** JRS-99-80 **EPA #:** MT-64 **EIS Class:** 2 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Phoxinus erythrogaster	1	2.6	0.02	NA	
Rhinichthys atratulus	107	156.9	1.46	107	107.8
Semotilus atromaculatus	29	212.2	1.98	29	30.3

Station #27 **Collection #:** JRS-99-81 **EPA #:** MT-69 **EIS Class:** 4 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Cottus bairdi	130	224.8	1.68	152	173.2
Rhinichthys atratulus	9	23.3	0.17	9	10.1

Station # 28 **Collection #:** JRS-00-73 **EPA #:** MT-70 **EIS Class:** 3 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Cottus bairdi	88	264.7	1.75	103	120.7
Rhinichthys atratulus	14	43.4	0.29	14	15.4
Semotilus atromaculatus	7	64.4	0.43	NA	

Station # 29 **Collection #:** JRS-00-76 **EPA #:** MT-79 **EIS Class:** 1 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	11	28.9	0.42	11	11.2
Semotilus atromaculatus	6	86.0	1.25	6	6.4

Station # 30 **Collection #:** JRS-00-79 **EPA #:** MT-80 **EIS Class:** 1 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	4	3.6	0.04	4	4.6
Semotilus atromaculatus	1	1.8	0.02	NA	

Station # 31 **Collection #:** JRS-00-80 **EPA #:** MT-82 **EIS Class:** 1 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
No Fish Caught					

Station # 32 **Collection #:** JRS-00-93 **EPA #:** MT-39 **EIS Class:** 0 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	20	20.6	0.20	NA	

Station # 33 **Collection #:** JRS-99-72 **EPA #:** MT-32 **EIS Class:** 2 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	61	453.9	2.06	64	69.7
Catostomus commersoni	3	65.3	0.30	NA	
Cottus bairdi	1	1.5	0.01	NA	
Etheostoma caeruleum	18	44.6	0.20	18	19.1
Etheostoma nigrum	5	4.9	0.02	5	7.2
Hypentelium nigricans	4	10.8	0.05	4	5.7
Lepomis cyanellus	24	357.7	1.62	25	28.8
Lepomis macrochirus	32	52.6	0.24	32	34.1
Luxilus chrysocephalus	2	38.1	0.17	NA	
Micropterus salmoides	1	2.1	0.01	NA	
Notropis rubellus	1	1.7	0.01	NA	
Pimephales notatus	2	9.6	0.04	NA	
Rhinichthys atratulus	1	3.6	0.02	NA	
Semotilus atromaculatus	12	179.0	0.81	12	12.2

Station # 34 **Collection #:** JRS-99-73 **EPA #:** MT-45 **EIS Class:** 1 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	37	43.2	0.39	37	38
Semotilus atromaculatus	6	9.8	0.09	6	6.9

Station # 35 **Collection #:** JRS-99-78 **EPA #:** NA **EIS Class:** 1 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	6	49.9	0.18	6	6.4
Cottus bairdi	12	48.3	0.17	NA	
Etheostoma flabellare	32	30.9	0.11	34	39.4
Hypentelium nigricans	5	62.5	0.22	NA	
Rhinichthys atratulus	111	170.9	0.60	129	147.9
Semotilus atromaculatus	41	295.9	1.04	62	102.3

Station # 36 **Collection #:** JRS-99-79 **EPA #:** MT-62 **EIS Class:** 3 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	5	148.1	0.70	5	6.2
Catostomus commersoni	1	265.0	1.25	NA	
Cottus bairdi	327	684.9	3.23	342	353.4
Etheostoma caeruleum	1	1.2	0.01	NA	
Hypentelium nigricans	7	472.1	2.23	7	7.8
Rhinichthys atratulus	44	71.7	0.34	46	50.7
*Salmo trutta**	3	NA	NA	NA	NA
Semotilus atromaculatus	35	250.2	1.18	61	121.2

* *Salmo trutta* were caught outside of the study site, measured (TL, mm), and released.

Station # 37 **Collection #:** JRS-99-82 **EPA #:** MT-70 **EIS Class:** 3 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
No Fish Caught					

Station # 38 **Collection #:** JRS-00-70 **EPA #:** MT-28 **EIS Class:** 2 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	18	155.2	0.38	18	19.4
Catostomus commersoni	19	172.0	0.42	19	19.5
Cottus bairdi	3	7.6	0.02	NA	
Hypentelium nigricans	6	420.4	1.04	NA	
Lepomis cyanellus	5	39.2	0.10	5	6.2
Lepomis macrochirus	16	23.5	0.06	25	26.5
Luxilus chrysocephalus	1	8.0	0.02	NA	
Rhinichthys atratulus	9	27.7	0.07	9	9.6
Semotilus atromaculatus	13	256.6	0.63	NA	

Station # 39 **Collection #:** JRS-00-74 **EPA #:** MT-63 **EIS Class:** 3 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Cottus bairdi	200	931.8	4.19	214	226.3
Hypentelium nigricans	10	1,158.2	5.21	NA	
Rhinichthys atratulus	62	174.7	0.79	62	63.1
Semotilus atromaculatus	2	4.9	0.02	NA	

Station # 40 **Collection #:** JRS-00-77 **EPA #:** MT-85 **EIS Class:** 1 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	18	76.8	0.18	18	19.4
Semotilus atromaculatus	33	500.9	1.20	34	37.6

Station # 41 **Collection #:** JRS-00-78 **EPA #:** MT-81 **EIS Class:** 1 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	6	26.4	0.10	NA	
Semotilus atromaculatus	20	344.2	1.37	20	20.5

Station # 42 **Collection #:** JRS-99-74 **EPA #:** MT-40 **EIS Class:** 3 **Stream Order:** 4

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	28	73.1	0.05	28	30.3
Cottus bairdi	187	245.7	0.18	207	223.7
Cyprinus carpio	1	9.7	0.01	NA	
Etheostoma blennioides	1	4.5	0.00	NA	
Etheostoma caeruleum	87	95.5	0.07	110	137
Etheostoma zonale	13	13.7	0.01	NA	
Hypentelium nigricans	24	570.7	0.42	33	55.2
Luxilus chrysocephalus	3	2.8	0.00	NA	
Micropterus dolomieu	2	5.6	0.00	NA	
Notropis ludibundus	45	39.2	0.03	47	51.8
Notropis photogenis	2	5.3	0.00	NA	
Notropis rubellus	43	73.7	0.05	43	44.4
Rhinichthys atratulus	27	57.9	0.04	35	53
Semotilus atromaculatus	35	208.6	0.15	37	41.9

Station # 43 **Collection #:** JRS-00-71 **EPA #:** MT-46 **EIS Class:** 3 **Stream Order:** 4

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	2	419.6	0.34	NA	
Cottus bairdi	149	312.3	0.26	165	180.1
Etheostoma blennioides	7	32.6	0.03	7	9.9
Etheostoma caeruleum	160	183.6	0.15	175	188.8
Etheostoma zonale	4	5.7	0.00	NA	
Hypentelium nigricans	27	1,817.4	1.49	30	37.7
Luxilus chrysocephalus	30	784.3	0.64	31	34.4
Micropterus dolomieu	13	1,598.3	1.31	13	14.5
Notropis photogenis	23	64.1	0.05	24	27.6
Notropis rubellus	94	231.6	0.19	95	97.7
Notropis volucellus	1	1.2	0.00	NA	
Rhinichthys atratulus	4	4.5	0.00	4	4.6
Semotilus atromaculatus	13	238.0	0.20	13	15.4

Station # 44 **Collection #:** JRS-00-72 **EPA #:** MT-47 **EIS Class:** 3 **Stream Order:** 4

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	2	385.2	0.22	2	6.9
Campostoma anomalum	86	590.2	0.33	94	104.5
Cottus bairdi	79	168.1	0.09	NA	
Ericymba buccata	19	27.1	0.02	19	19.5
Etheostoma blennioides	2	9.1	0.01	NA	
Etheostoma caeruleum	74	72.7	0.04	NA	
Etheostoma zonale	1	0.9	0.00	NA	
Hypentelium nigricans	20	1,400.6	0.79	22	28.6
Lampetra aepyptera	1	1.3	0.00	NA	
Lepomis macrochirus	1	6.3	0.00	NA	
Luxilus chrysocephalus	47	1,195.3	0.67	58	75.9
Micropterus dolomieu	9	1,169.5	0.66	9	9.6
Moxostoma erythrurum	4	2,166.5	1.22	NA	
Notropis photogenis	10	20.9	0.01	10	10.2
Notropis rubellus	86	199.4	0.11	107	131.7
Notropis volucellus	12	12.7	0.01	NA	
Rhinichthys atratulus	12	18.7	0.01	12	12.8
Semotilus atromaculatus	23	275.1	0.15	27	37.4

Station # 45 **Collection #:** JRS-99-75 **EPA #:** MT-48 **EIS Class:** 3 **Stream Order:** 5

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	8	793.7	0.50	8	8.3
Campostoma anomalum	14	106.7	0.07	14	16.6
Cottus bairdi	6	21.8	0.01	NA	
Cyprinella spiloptera	1	3.0	0.00	NA	
Etheostoma blennioides	14	34.3	0.02	15	19.9
Etheostoma caeruleum	218	151.8	0.10	NA	
Etheostoma nigrum	15	10.8	0.01	18	27.9
Etheostoma variatum	9	38.1	0.02	NA	
Etheostoma zonale	22	19.4	0.01	27	39.9
Hypentelium nigricans	40	1,439.8	0.91	41	44.5
Lepomis cyanellus	1	10.8	0.01	NA	
Lepomis macrochirus	2	5.2	0.00	NA	
Luxilus chrysocephalus	19	71.6	0.05	22	30.9
Micropterus dolomieu	12	1,462.7	0.92	12	13.6
Notropis ludibundus	46	45.0	0.03	NA	
Notropis photogenis	8	18.6	0.01	8	10.5
Notropis rubellus	66	98.7	0.06	77	92.1
Pimephales notatus	4	15.1	0.01	NA	
Rhinichthys atratulus	1	0.2	0.00	NA	
Semotilus atromaculatus	1	25.5	0.02	NA	

Table 3B. Total number caught (Number), total biomass (g), biomass per square meter (g/sq.m.), population estimate (based on 3-pass depletion), and the associated upper 95% confidence limit on the estimate (Upper CL) by species for fish collections completed in the New River Drainage (Twentymile Creek watershed), West Virginia during Fall 1999 and Spring 2000. NA in the Estimate column indicates samples where an estimate could not be calculated due to too few fish being caught, an irregular depletion pattern, or all fish being caught in the first pass.

Station # 46 **Collection #:** JRS-00-88 **EPA #:** MT-93 **EIS Class:** 0 **Stream Order:** 1

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
No Fish Caught					

Station # 47 **Collection #:** JRS-99-86 **EPA #:** MT-98 **EIS Class:** 2 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Catostomus commersoni	1	29.5	0.10	NA	
Rhinichthys atratulus	40	77.9	0.26	50	67.9
Semotilus atromaculatus	2	96.5	0.32	NA	

Station # 48 **Collection #:** JRS-00-83 **EPA #:** NA **EIS Class:** 1 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	13	150.3	0.32	13	14.5
Catostomus commersoni	8	93.2	0.20	NA	
Cottus bairdi	22	63.6	0.13	22	24.3
Etheostoma caeruleum	2	3.6	0.01	NA	
Etheostoma flabellare	69	113.1	0.24	80	95
Hypentelium nigricans	1	32.2	0.07	NA	
Rhinichthys atratulus	112	226.1	0.48	118	125.9
Semotilus atromaculatus	50	201.1	0.43	51	54.2

Station # 49 **Collection #:** JRS-00-84 **EPA #:** MT-87 **EIS Class:** 2 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Etheostoma flabellare	5	8.1	0.03	NA	
Rhinichthys atratulus	72	116.0	0.49	74	78.3
Semotilus atromaculatus	12	41.5	0.18	12	13.6

Station # 50 **Collection #:** JRS-00-85 **EPA #:** MT-95 **EIS Class:** 0 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	7	20.0	0.30	7	7.3
Cottus bairdi	1	0.8	0.01	NA	
Etheostoma caeruleum	38	25.9	0.39	38	40.2
Etheostoma flabellare	2	2.4	0.04	NA	
Semotilus atromaculatus	4	4.8	0.07	NA	

Station # 51 **Collection #:** JRS-00-86 **EPA #:** NA **EIS Class:** 0 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	25	140.2	1.44	25	26.8
Etheostoma caeruleum	17	8.5	0.09	17	18.8
Etheostoma flabellare	12	11.5	0.12	NA	
Etheostoma nigrum	1	4.0	0.04	NA	
Luxilus chrysocephalus	5	31.6	0.32	NA	
Semotilus atromaculatus	5	83.0	0.85	5	5.5

Station # 52 **Collection #:** JRS-00-87 **EPA #:** MT-91 **EIS Class:** 0 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	1	18.6	0.06	NA	
Catostomus commersoni	4	79.3	0.27	NA	
Cottus bairdi	30	125.5	0.42	31	35.0
Etheostoma flabellare	28	51.9	0.17	29	32.9
Rhinichthys atratulus	89	175.1	0.59	89	91.1
Semotilus atromaculatus	31	113.9	0.38	31	31.4

Station # 53 **Collection #:** JRS-00-89 **EPA #:** MT-94 **EIS Class:** 0 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Cottus bairdi	3	6.0	0.07	NA	
Rhinichthys atratulus	7	13.2	0.15	7	8.4
Semotilus atromaculatus	3	15.0	0.17	NA	

Station # 54 **Collection #:** JRS-99-84 **EPA #:** NA **EIS Class:** 2 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	15	952.5	0.74	15	16.6
Campostoma anomalum	27	216.8	0.17	31	40.7
Cyprinella galactura	18	135.9	0.11	18	19.7
Etheostoma blennioides	2	5.8	0.00	NA	
Etheostoma caeruleum	36	24.5	0.02	46	65.1
Etheostoma flabellare	5	8.0	0.01	NA	
Etheostoma nigrum	4	3.5	0.00	NA	
Hypentelium nigricans	13	632.3	0.49	13	14.4
Lepomis cyanellus	6	91.1	0.07	6	7.7
Luxilus albeolus	8	72.9	0.06	8	8.6
Luxilus chrysocephalus	1	21.7	0.02	NA	
Micropterus dolomieu	3	183.4	0.14	3	4.1
Nocomis platyrhynchus	46	1,112.8	0.87	50	57.6
Notropis rubellus	16	19.6	0.02	17	21.2
Notropis telescopus	75	97.2	0.08	82	92.1
Notropis volucellus	1	2.1	0.00	NA	
Pimephales notatus	3	8.0	0.01	NA	

Station # 55 **Collection #:** JRS-99-85 **EPA #:** NA **EIS Class:** 2 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	72	271.2	0.90	81	93.4
Etheostoma caeruleum	95	95.1	0.32	101	109.3
Etheostoma flabellare	8	12.8	0.04	8	9.8
Hypentelium nigricans	1	46.0	0.15	NA	
Lepomis cyanellus	11	202.7	0.67	NA	
Lepomis cyanellus x L.macrochirus	1	11.0	0.04	NA	
Nocomis platyrhynchus	72	281.9	0.94	74	78.3
Rhinichthys atratulus	46	50.8	0.17	51	59.9
Semotilus atromaculatus	21	69.4	0.23	27	42.8

Station # 56 **Collection #:** JRS-00-81 **EPA #:** MT-86 **EIS Class:** 2 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Catostomus commersoni	11	296.2	1.00	NA	
Cottus bairdi	3	16.2	0.05	3	4.1
Etheostoma caeruleum	1	1.1	0.00	NA	
Etheostoma flabellare	24	31.6	0.11	29	41.3
Rhinichthys atratulus	70	144.2	0.49	71	74.2
Semotilus atromaculatus	40	265.5	0.89	42	46.9

Station # 57 **Collection #:** JRS-00-82 **EPA #:** NA **EIS Class:** 2 **Stream Order:** 4

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	17	192.1	0.19	20	29.3
Catostomus commersoni	15	372.9	0.36	15	17.4
Cottus bairdi	21	86.5	0.08	22	25.9
Etheostoma caeruleum	18	29.4	0.03	19	23.2
Etheostoma flabellare	23	48.0	0.05	NA	
Hypentelium nigricans	10	750.2	0.72	10	12.5
Luxilus albeolus	12	114.2	0.11	12	14.1
Rhinichthys atratulus	69	152.2	0.15	107	163
Semotilus atromaculatus	53	629.5	0.61	76	113.1

Station # 58 **Collection #:** JRS-99-83 **EPA #:** NA **EIS Class:** 2 **Stream Order:** 4

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	17	735.6	0.92	19	25.7
Campostoma anomalum	63	343.7	0.43	65	69.7
Catostomus commersoni	4	246.2	0.31	4	5.7
Cottus bairdi	2	5.0	0.01	NA	
Ericymba buccata	7	18.3	0.02	NA	
Etheostoma caeruleum	31	22.9	0.03	32	35.9
Etheostoma flabellare	2	0.8	0.00	NA	
Etheostoma nigrum	9	10.0	0.01	9	9.6
Hypentelium nigricans	20	351.7	0.44	27	46.3
Lepomis cyanellus	11	154.7	0.19	NA	
Luxilus albeolus	30	160.0	0.20	31	34.7
Micropterus dolomieu	7	125.8	0.16	7	8.4
Nocomis platyrhynchus	15	79.4	0.10	15	16.3
Notropis telescopus	3	9.4	0.01	NA	
Pimephales notatus	1	2.4	0.00	NA	
Semotilus atromaculatus	26	298.9	0.37	26	26.4

Table 4B. Total number caught (Number), total biomass (g), biomass per square meter (g/sq.m.), population estimate (based on 3-pass depletion), and the associated upper 95% confidence limit on the estimate (Upper CL) by species for fish collections completed in the Cumberland, Kentucky, and North Fork of the Kentucky River Drainages, Kentucky during Spring 2000. NA in the Estimate column indicates samples where an estimate could not be calculated due to too few fish being caught, an irregular depletion pattern, or all fish being caught in the first pass.

Station # 59 **Collection #:** JRS-00-95 **EPA #:** 8 **EIS Class:** 2 **Stream Order:** 4

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	26	2,011.2	1.49	33	49.1
Campostoma anomalum	94	570.8	0.42	128	167.5
Etheostoma baileye	4	2.7	0.00	NA	
Etheostoma caeruleum	115	89.8	0.07	240	421.9
Etheostoma flabellare	32	22.9	0.02	33	36.8
Etheostoma kennicotti	7	6.2	0.00	NA	
Hypentelium nigricans	30	1,085.3	0.80	43	71.8
Lepomis auritus	39	1,361.7	1.01	73	151.8
Luxilus chrysocephalus	25	235.3	0.17	29	39.0
Micropterus dolomieu	6	141.3	0.10	NA	
Micropterus punctulatus	11	456.5	0.34	NA	
Notropis rubellus	3	5.4	0.00	NA	
Pimephales notatus	37	68.6	0.05	NA	
Semotilus atromaculatus	1	3.7	0.00	NA	

Station # 60 **Collection #:** JRS-00-96 **EPA #:** 6 **EIS Class:** 2 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	154	1,178.6	3.12	155	157.7
Etheostoma caeruleum	121	167.6	0.44	131	142.0
Etheostoma flabellare	16	18.9	0.05	16	17.5
Hypentelium nigricans	7	119.0	0.32	7	7.3
Pimephales notatus	1	1.8	0.00	NA	
Rhinichthys atratulus	276	444.7	1.18	288	298.0
Semotilus atromaculatus	306	1,045.5	2.77	314	321.8

Station # 61 **Collection #:** JRS-00-97 **EPA #:** NA **EIS Class:** 0 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	3	11.7	0.01	3	4.1
Campostoma anomalum	8	47.7	0.05	8	9.8
Etheostoma baileye	3	2.2	0.00	NA	
Etheostoma blennioides	1	4.6	0.00	NA	
Etheostoma caeruleum	88	71.1	0.07	96	106.5
Etheostoma kennicotti	20	14.7	0.01	20	20.3
Hypentelium nigricans	15	1,408.2	1.37	NA	
Lepomis auritus	148	3,985.2	3.88	192	231.4
Lepomis macrochirus	88	1,350.7	1.31	110	135.7
Luxilus chrysocephalus	4	14.2	0.01	4	7.1
Lythrurus ardens	5	4.6	0.00	5	5.5
Micropterus punctulatus	2	188.2	0.18	NA	
Notropis rubellus	1	0.5	0.00	NA	
Phoxinus erythrogaster	1	2.9	0.00	NA	
Pimephales notatus	83	113.5	0.11	93	105.6
Semotilus atromaculatus	24	149.3	0.15	25	28.8

Station # 62 **Collection #:** JRS-00-94 **EPA #:** 12 **EIS Class:** 0 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	4	113.8	0.27	NA	
Campostoma anomalum	100	180.3	0.43	101	104.1
Catostomus commersoni	1	0.1	0.00	NA	
Etheostoma baileye	11	8.6	0.02	11	13.8
Etheostoma blennioides	50	75.9	0.18	52	56.4
Etheostoma caeruleum	196	139.8	0.33	199	203.6
Etheostoma flabellare	91	102.6	0.24	92	95
Etheostoma nigrum	23	10.7	0.03	24	27.6
Etheostoma sagitta	1	1.6	0.00	NA	
Hypentelium nigricans	13	133.3	0.31	13	13.5
Lepomis megalotis	1	30.0	0.07	NA	
Luxilus chrysocephalus	125	272.4	0.64	129	134.8
Lythrurus ardens	35	31.4	0.07	35	36.5
Micropterus dolomieu	1	266.0	0.63	NA	
Moxostoma erythrurum	3	706.0	1.67	NA	
Oncorhynchus mykiss	1	81.0	0.19	NA	
Percina maculata	10	18.7	0.04	10	11.4
Percina stictogaster	6	8.9	0.02	6	7.7
Pimephales notatus	68	71.2	0.17	71	76.3
Semotilus atromaculatus	44	101.7	0.24	47	53.1

Station # 63 **Collection #:** JRS-00-98 **EPA #:** 13 **EIS Class:** 0 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	41	122.1	0.53	41	42.6
Ericymba buccata	2	5.1	0.02	NA	
Etheostoma baileye	21	12.5	0.05	21	22.1
Etheostoma blennioides	59	72.8	0.31	61	65.8
Etheostoma caeruleum	97	63.2	0.27	109	122.8
Etheostoma flabellare	59	44.4	0.19	65	74.6
Etheostoma nigrum	64	27.8	0.12	70	79.3
Luxilus chrysocephalus	6	8.9	0.04	6	6.9
Percina stictogaster	5	5.0	0.02	5	6.2
Phoxinus erythrogaster	108	54.3	0.23	111	116.0
Pimephales notatus	2	1.9	0.01	NA	
Semotilus atromaculatus	95	273.2	1.18	97	101.0

Station # 64 **Collection #:** JRS-00-99 **EPA #:** 3 **EIS Class:** 2 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	5	29.4	0.17	NA	
Catostomus commersoni	4	62.3	0.36	NA	
Etheostoma flabellare	5	5.5	0.03	NA	
Hypentelium nigricans	1	10.9	0.06	NA	
Lepomis cyanellus	3	5.5	0.03	NA	
Luxilus chrysocephalus	1	3.6	0.02	NA	
Moxostoma erythrurum	1	7.1	0.04	NA	
Pimephales notatus	6	9.7	0.06	NA	
Rhinichthys atratulus	35	75.1	0.43	39	47.5
Semotilus atromaculatus	30	235.4	1.35	40	61.6

Station # 65 **Collection #:** JRS-00-100 **EPA #:** 2 **EIS Class:** 2 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	1	5.1	0.02	NA	
Etheostoma caeruleum	119	144.2	0.48	120	123.1
Hypentelium nigricans	6	57.1	0.19	6	6.9
Lepomis macrochirus	1	1.7	0.01	NA	
Rhinichthys atratulus	294	610.8	2.05	295	297.4
Semotilus atromaculatus	93	294.9	0.99	98	105.1

Station # 66 **Collection #:** JRS-00-101 **EPA #:** 9 **EIS Class:** 3 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	32	99.3	0.12	32	34.1
Catostomus commersoni	2	14.1	0.02	NA	
Etheostoma baileye	3	2.6	0.00	3	4.1
Etheostoma blennioides	3	3.7	0.00	NA	
Etheostoma caeruleum	116	65.5	0.08	150	184.6
Hypentelium nigricans	25	246.1	0.30	25	25.4
Lepomis hybrid	1	7.4	0.01	NA	
Luxilus chrysocephalus	15	48.7	0.06	15	15.9
Micropterus dolomieu	1	3.0	0.00	NA	
Notropis ludibundus	1	1.3	0.00	NA	
Notropis rubellus	1	1.5	0.00	NA	
Pimephales notatus	1	2.1	0.00	NA	
Semotilus atromaculatus	80	304.6	0.37	85	92.4

Station # 67 **Collection #:** JRS-00-102 **EPA #:** 14 **EIS Class:** 2 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	1	11.2	0.04	NA	
Lepomis macrochirus	1	45.4	0.16	NA	
Rhinichthys atratulus	2	7.9	0.03	NA	
Semotilus atromaculatus	90	285.3	1.01	125	166.9

Station # 68 **Collection #:** JRS-00-103 **EPA #:** 5 **EIS Class:** 2 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	1	8.3	0.08	NA	
Campostoma anomalum	7	8.3	0.08	7	7.8
Etheostoma baileye	1	0.4	0.00	NA	
Etheostoma blennioides	5	6.7	0.06	5	6.2
Etheostoma caeruleum	7	3.6	0.03	7	8.4
Etheostoma variatum	1	0.6	0.01	NA	
Hypentelium nigricans	2	15.8	0.15	NA	
Luxilus chrysocephalus	76	113.2	1.10	76	76.2
Nocomis micropogon	1	4.0	0.04	NA	
Noturus miurus	1	4.0	0.04	NA	
Pimephales notatus	1	1.4	0.01	NA	
Semotilus atromaculatus	9	66.8	0.65	9	11.2

Station # 69 **Collection #:** JRS-00-104 **EPA #:** 4 **EIS Class:** 2 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ameiurus natalis	2	65.9	0.21	NA	
Campostoma anomalum	15	51.4	0.16	16	20.5
Catostomus commersoni	1	8.4	0.03	NA	
Etheostoma baileye	5	3.8	0.01	5	6.2
Etheostoma blennioides	3	8.3	0.03	NA	
Etheostoma caeruleum	9	7.5	0.02	9	10.6
Etheostoma variatum	1	5.4	0.02	NA	
Lepomis cyanellus	3	22.2	0.07	NA	
Lepomis macrochirus	6	60.6	0.19	6	6.4
Luxilus chrysocephalus	39	120.0	0.38	40	43.4
Notropis rubellus	3	4.2	0.01	NA	
Pimephales notatus	4	11.1	0.04	NA	
Rhinichthys atratulus	2	2.4	0.01	NA	
Semotilus atromaculatus	28	235.8	0.74	28	29.1

Station # 70 **Collection #:** JRS-00-105 **EPA #:** 1 **EIS Class:** 2 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Hypentelium nigricans	1	38.2	0.27	NA	
Semotilus atromaculatus	22	153.9	1.10	NA	

Station # 71 **Collection #:** JRS-00-106 **EPA #:** 10 **EIS Class:** 0 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	93	295.0	1.40	93	94.7
Ericymba buccata	44	52.5	0.25	44	45.5
Etheostoma baileye	60	53.5	0.25	60	61.0
Etheostoma blennioides	19	34.3	0.16	19	19.7
Etheostoma caeruleum	75	66.6	0.32	75	75.5
Etheostoma flabellare	85	69.5	0.33	86	88.6
Etheostoma nigrum	124	52.1	0.25	127	132.1
Etheostoma sagitta	1	3.3	0.02	NA	
Hypentelium nigricans	4	30.2	0.14	4	4.6
Luxilus chrysocephalus	47	132.1	0.63	NA	
Percina maculata	1	2.1	0.01	NA	
Semotilus atromaculatus	101	414.6	1.96	102	104.8

Station # 72 **Collection #:** JRS-00-107 **EPA #:** 11 **EIS Class:** 0 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	113	131.1	1.12	113	113.6
Etheostoma baileye	7	3.9	0.03	7	7.8
Etheostoma blennioides	7	8.8	0.07	7	8.4
Etheostoma caeruleum	20	12.1	0.10	20	20.9
Etheostoma flabellare	3	4.6	0.04	NA	
Etheostoma nigrum	2	1.0	0.01	NA	
Luxilus chrysocephalus	12	32.4	0.28	12	12.4
Percina maculata	2	2.7	0.02	NA	
Semotilus atromaculatus	54	204.7	1.74	55	58.2

Station # 73 **Collection #:** JRS-00-108 **EPA #:** 7 **EIS Class:** 2 **Stream Order:** 4

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	3	0.9	0.00		
Catostomus commersoni	19	5.1	0.01	23	34.5
Etheostoma blennioides	1	1.5	0.00	NA	
Hypentelium nigricans	6	0.6	0.00	NA	
Lampetra aepyptera	2	3.9	0.01	NA	
Pimephales notatus	3	10.4	0.02	NA	
Semotilus atromaculatus	42	91.7	0.22	42	43.4

APPENDIX C. Total number caught (Number), total biomass (g), biomass per square meter (g/sq.m.), population estimate (based on 3-pass depletion), and the associated upper 95% confidence limit on the estimate (Upper CL) by species for fish collections completed in the Guyandotte River Drainage (Mud River, Big Ugly, and Buffalo Creek watersheds) in Fall 2001. NA in the Estimate column indicates samples where an estimate could not be calculated due to too few fish being caught, an irregular depletion pattern, or all fish being caught in the first pass.

Station # 7 **Collection #:** JRS-01-84 **EPA #:** MT-18 **EIS Class:** 2 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Lepomis cyanellus	6	59	0.351	NA	
Semotilus atromaculatus	3	40	0.930	NA	

Station # 12 **Collection #:** JRS-01-87 **EPA #:** MT-14 **EIS Class:** 2 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	2	6	0.037	NA	
Catostomus commersoni	2	25	0.155	NA	
Etheostoma caeruleum	1	1	0.006	NA	
Lepomis cyanellus	2	20	0.124	NA	
Pimephales notatus	1	6	0.037	NA	
Semotilus atromaculatus	13	304	1.882	NA	

Station # 17 **Collection #:** JRS-01-85 **EPA #:** NA **EIS Class:** 2 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ameiurus melas	1	157	0.561	NA	
Campostoma anomalum	1	12	0.043	NA	
Catostomus commersoni	2	10	0.036	NA	
Etheostoma blennioides	1	5	0.018	NA	
Etheostoma caeruleum	1	1	0.004	NA	
Lepomis cyanellus	12	92	0.329	12	14.1
Lepomis macrochirus	1	7	0.025	NA	
Pimephales promelas	2	4	0.014	4	5.7
Semotilus atromaculatus	11	259	0.925	12	17.6

Station # 18 **Collection #:** JRS-01-86 **EPA #:** MT-15 **EIS Class:** 2 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ameiurus nebulosus	1	83	0.638	NA	
Campostoma anomalum	1	2	0.015	NA	
Hypentelium nigricans	1	44	0.338	NA	
Lepomis cyanellus	12	155	1.192	12	14.1
Pimephales promelas	3	8	0.062	NA	
Semotilus atromaculatus	2	46	0.354	NA	

Station # 19 **Collection #:** JRS-01-88 **EPA #:** MT-07 **EIS Class:** 3 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ericymba bucatta	1	3	0.006	NA	
Etheostoma caeruleum	10	9	0.018	10	10.9
Etheostoma flabellare	12	10	0.020	12	13.2
Etheostoma nigrum	5	3	0.006	NA	
Lepomis cyanellus	22	91	0.181	23	26.8
Pimephales notatus	1	1	0.002	NA	
Rhinichthys atratulus	6	13	0.026	6	7.0
Semotilus atromaculatus	50	201	0.399	51	54.0

Station # 20 **Collection #:** JRS-01-89 **EPA #:** MT-05 **EIS Class:** 3 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	11	48	0.135	11	12.8
Catostomus commersoni	13	201	0.565	13	15.4
Clinostomus funduloides	2	8	0.022	NA	
Ericymba buccata	8	21	0.059	8	10.5
Etheostoma caeruleum	4	5	0.014	4	5.7
Etheostoma flabellare	16	21	0.059	16	16.9
Etheostoma nigrum	10	10	0.028	10	11.4
Labidesthes sicculus	16	22	0.062	16	18.3
Lampetra aepyptera	2	3	0.008	NA	
Lepomis cyanellus	38	301	0.846	NA	
Lepomis macrochirus	1	4	0.011	NA	
Lepomis megalotis	1	14	0.039	NA	
Luxilus chrysocephalus	1	10	0.028	NA	
Micropterus punctulatus	3	6	0.017	3	4.1
Percina caprodes	3	9	0.025	3	4.1
Pimephales notatus	4	10	0.028	4	4.7
Rhinichthys atratulus	3	8	0.022	3	4.1
Semotilus atromaculatus	115	911	2.559	127	140.2

Station # 22 **Collection #:** JRS-01-82 **EPA #:** MT-23 **EIS Class:** 3 **Stream Order:** 4

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ameiurus natalis	1	272	0.389	NA	
Campostoma anomalum	29	193	0.276	29	29.2
Etheostoma blennioides	10	20	0.029	10	10.2
Etheostoma caeruleum	22	16	0.023	23	27.2
Etheostoma nigrum	2	1	0.001	NA	
Etheostoma zonale	10	10	0.014	12	21.2
Hypentelium nigricans	2	89	0.127	NA	
Lepomis cyanellus	16	291	0.416	17	21.2
Luxilus chrysocephalus	1	4	0.006	NA	
Micropterus punctulatus	1	314	0.449	NA	
Notropis ludibundus	1	2	0.003	NA	
Semotilus atromaculatus	12	78	0.111	12	12.8

Station # 23 **Collection #:** JRS-01-83 **EPA #:** MT-17 **EIS Class:** 3 **Stream Order:** 4

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	1	113	0.232	NA	
Ameiurus natalis	2	392	0.804	NA	
Campostoma anomalum	1	8	0.016	NA	
Catostomus commersoni	2	107	0.219	NA	
Lepomis macrochirus	1	8	0.016	NA	
Lepomis megalotis	17	300	0.615	19	25.7
Luxilus chrysocephalus	1	39	0.080	NA	
Semotilus atromaculatus	4	283	0.581	4	7.1

Station # 74 **Collection #:** JRS-01-90 **EPA #:** NA **EIS Class:** 0 **Stream Order:** 4

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	1	41	0.045	NA	
Campostoma anomalum	11	13	0.014	11	12.3
Cyprinella spiloptera	11	20	0.022	11	11.2
Ericymba buccata	29	29	0.032	34	45.0
Etheostoma blennioides	7	12	0.013	7	7.3
Etheostoma caeruleum	22	13	0.014	22	22.1
Etheostoma flabellare	11	10	0.011	11	11.5
Etheostoma nigrum	84	40	0.044	84	86.0
Etheostoma variatum	4	7	0.008	NA	
Etheostoma zonale	5	3	0.003	NA	
Hypentelium nigricans	9	454	0.501	NA	
Lampetra aepyptera	30	127	0.140	31	35.0
Lepomis macrochirus	4	46	0.051	NA	
Lepomis megalotis	19	216	0.238	19	21.0
Luxilus chrysocephalus	81	230	0.254	82	84.9
Micropterus dolomieu	1	1	0.001	NA	
Micropterus punctulatus	19	315	0.347	19	20.3
Moxostoma erythrurum	17	423	0.467	17	18.1
Notropis ludibundus	2	3	0.003	NA	
Notropis rubellus	4	8	0.009	4	4.7
Noturus miurus	4	3	0.003	4	5.7
Percina maculata	3	4	0.004	NA	
Pimephales notatus	80	114	0.126	96	115.8
Semotilus atromaculatus	46	126	0.139	48	52.5

Station # 75 **Collection #:** JRS-01-91 **EPA #:** NA **EIS Class:** 0 **Stream Order:** 4

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	2	2	0.003	NA	
Campostoma anomalum	56	110	0.143	56	57.5
Ericymba buccata	16	24	0.031	25	55.2
Etheostoma blennioides	26	38	0.050	29	36.6
Etheostoma caeruleum	77	33	0.043	81	87.5
Etheostoma flabellare	15	14	0.018	15	16.3
Etheostoma nigrum	89	45	0.059	100	113.4
Etheostoma variatum	14	47	0.061	14	15.4
Etheostoma zonale	16	7	0.009	17	21.2
Hypentelium nigricans	24	348	0.454	25	28.9
Lampetra aepyptera	4	7	0.009	4	4.7
Lepomis gibbosus	3	28	0.037	NA	
Lepomis megalotis	12	129	0.168	13	18.1
Luxilus chrysocephalus	207	809	1.055	250	282.0
Micropterus dolomieu	4	9	0.012	NA	
Micropterus punctulatus	4	58	0.076	4	5.7
Notropis ludibundus	14	20	0.026	16	23.6
Notropis rubellus	3	5	0.007	NA	
Percina maculata	4	5	0.007	NA	
Pimephales notatus	174	271	0.353	198	218.0
Semotilus atromaculatus	54	340	0.443	97	178.1

Station # 76 **Collection #:** JRS-01-92 **EPA #:** NA **EIS Class:** 0 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	13	52	0.452	13	13.4
Ericymba buccata	23	34	0.296	23	23.1
Etheostoma caeruleum	30	29	0.252	30	31.3
Etheostoma flabellare	5	7	0.061	NA	
Etheostoma nigrum	2	2	0.017	NA	
Lepomis megalotis	2	16	0.139	NA	
Luxulus chrysocephalus	9	11	0.096	NA	
Micropterus dolomeiu	2	4	0.035	NA	
Percina maculatum	2	4	0.035	NA	
Pimephales notatus	4	11	0.096	NA	
Rhinichthys atratulus	29	46	0.400	29	29.3
Semotilus atromaculatus	50	234	2.035	50	52.1

Station # 77 **Collection #:** JRS-01-93 **EPA #:** NA **EIS Class:** 0 **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	3	11	0.099	3	4.1
Catostomus commersoni	2	19	0.171	NA	
Clinostomus funduloides	5	8	0.072	5	5.5
Ericymba buccata	17	32	0.289	17	17.8
Etheostoma caeruleum	24	22	0.198	24	25.3
Etheostoma flabellare	5	8	0.072	5	5.5
Etheostoma nigrum	5	3	0.027	5	5.5
Hypentelium nigricans	1	16	0.144	NA	
Lampetra aepyptera	1	2	0.018	NA	
Luxilus chrysocephalus	2	9	0.081	NA	
Pimephales notatus	5	14	0.126	5	5.5
Rhinichthys atratulus	18	18	0.162	18	19.7
Semotilus atromaculatus	57	300	2.707	57	59.2

Station # 78 **Collection #:** JRS-01-94 **EPA #:** NA **EIS Class:** 0 **Stream Order:** 3

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Ambloplites rupestris	7	7	0.021	7	7.3
Campostoma anomalum	29	92	0.270	29	29.1
Ericymba buccata	50	79	0.232	50	50.2
Etheostoma blennioides	5	9	0.026	5	5.5
Etheostoma caeruleum	144	91	0.267	146	149.7
Etheostoma flabellare	14	13	0.038	14	14.4
Etheostoma nigrum	36	19	0.056	36	37.1
Etheostoma variatum	6	28	0.082	NA	
Hypentelium nigricans	7	176	0.517	7	8.4
Lampetra aepyptera	4	16	0.047	4	7.1
Lepomis megalotis	23	339	0.995	23	24.1
Luxilus chrysocephalus	47	94	0.276	47	47.2
Micropterus dolomieu	5	111	0.326	5	6.2
Percina maculata	6	10	0.029	6	6.4
Pimephales notatus	66	53	0.156	69	74.5
Rhinichthys atratulus	2	2	0.006	NA	
Semotilus atromaculatus	74	215	0.631	74	74.4

Station # 79 **Collection #:** JRS-01-95 **EPA #:** NA **EIS Class:** ? **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Campostoma anomalum	154	711	2.045	157	162.0
Catostomus commersoni	25	320	0.920	25	26.0
Ericymba buccata	21	59	0.170	21	21.1
Hypentelium nigricans	4	41	0.118	NA	
Pimephales notatus	9	42	0.121	9	9.2
Rhinichthys atratulus	141	224	0.644	141	141.8
Semotilus atromaculatus	314	2294	6.598	344	348.6

Station # 80 **Collection #:** JRS-01-96 **EPA #:** NA **EIS Class:** ? **Stream Order:** 1

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	92	135	1.753	92	92.4
Semotilus atromaculatus	52	220	2.857	52	52.1

Station # 81 **Collection #:** JRS-01-97 **EPA #:** NA **EIS Class:** ? **Stream Order:** 2

Species	Number	Biomass (g)	g/m^2	Estimate	Upper CL
Rhinichthys atratulus	38	72	0.608	38	38.1
Semotilus atromaculatus	40	69	0.583	40	40.1

APPENDIX D. Laboratory data sheets for chemical analysis conducted by Research Environmental & Industrial Consultants, Inc (REIC) for water samples collected at the 16 sites sampled for fishes (Table 10) in the Mud River, Big Ugly, and Guyandotte drainages that were sampled in September 2001. A single water sample was collected at each site (according to directions provided by the EPA) and sent to the REIC for laboratory analysis of total metals (mg/L of aluminum, iron, arsenic, copper, and selenium) and hardness (as mg/L $CaCO_3$).

Kentucky Mountaintop Mining
Benthic Macroinvertebrate Survey

Central Appalachian Ecoregion, Kentucky

October 2001

Science and Ecosystem Support Division
Ecological Assessment Branch
980 College Station Road, Athens, Georgia 30605

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[1]U.S. Environmental Protection Agency, Region 4, Science and Ecosystem Support Division, 980 College Station Road, Athens, Georgia 30605.
[2]U.S. Environmental Protection Agency, Region 4, Water Management Division, 61 Forsyth street, S.W., Atlanta, Georgia 30303.
[3]Kentucky Division of Water, Ecological Support Section, 14 Reilly Road, Frankfort, Kentucky 40601.

EXECUTIVE SUMMARY

In response to a request by the EPA Region 4 Water Management Division, an assessment of stream macroinvertebrate community health was conducted by EPA Region 4 Science and Ecosystem Support Division staff at 12 sites in the Eastern Coalfield area of Kentucky, May 1-4, 2000. The study was designed to determine if streams in mined watersheds were being impacted by a practice known as "mountaintop mining and valley fill " (MTM/VF). This mining approach consists of disrupting or removing the tops of mountains to access multiple coal seams, and depositing the bulk of the overburden in adjacent valleys burying first- and second-order streams under tons of soil and rock.

The eight mining-related sites selected for this study were located in Breathitt, Perry, Knot, and Bell Counties. These locations represent sites downstream of active mining, inactive mining and/or reclaimed mining sites. Four reference sites were located in the Robinson Forest and Redbird Wildlife Management Areas located in Breathitt, Knott, Clay, and Leslie Counties, areas within which mining has not occurred. At each study site, a habitat evaluation was performed, *in situ* water quality was measured, and macroinvertebrate samples were collected. In addition, sediment characterization samples were collected at eight of the 12 sites. Habitat evaluation, collection of macroinvertebrates, and interpretation of results were based on US EPA Rapid Bioassessment Protocols and EPA Region 4 Standard Operating Procedures. Sediment characterization sampling and interpretation techniques followed US EPA EMAP protocols.

Various measures of *in situ* water quality, habitat quality and macroinvertebrate community structure were found to be related to mining activities. In particular, conductivity was considerably higher at all mined sites than it was at reference sites. Conductivity showed the strongest correlation to indicators of macroinvertebrate community health (i.e., % ephemeroptera, taxa richness, EPT index, biotic index, and MBI) suggesting this as either a route by which impairment occurred in mined areas, or that conductivity is a surrogate for other factors that were not measured. Severe impact to the mayfly (Ephemeroptera) fauna was exhibited at all mined sites. Habitat scores, generally lower at sampling locations downstream of mined areas than at reference sites, were correlated to several measures of diversity and dominance of key groups of macroinvertebrates. Especially noted was the decrease in pollution-sensitive macroinvertebrates (Ephemeroptera, Plecoptera, and Trichoptera) at the mined watersheds. Sediment deposition scores were also strongly correlated with conductivity.

In summary, impacts of MTM/VF activities in eastern Kentucky were evident based on stream biological and habitat indicators. Mine sites generally had higher conductivity, greater sediment deposition, smaller substrate particle sizes, and a decrease in pollution sensitive macroinvertebrates with an associated decrease in taxa diversity compared to reference sites.

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1.0 INTRODUCTION

The purpose of this study was to evaluate the ecological health of first to third order streams subjected to mountain top mining/valley fill (MTM/VF) practices in the Central Appalachian Ecoregion of Kentucky (Omernik 1987). Mountaintop mining is the term that describes a mining practice in which millions of tons of dirt and rock are removed from mountaintops in order to extract multiple seams of coal. The resulting overburden is often placed in the adjacent valleys resulting in the stream being completely filled or receiving excessive sedimentation. Both pre-mining deforestation and mountaintop mining lead to accelerated sediment deposition, disrupted hydrology, and habitat degradation affecting the stream biota. The U.S. Fish and Wildlife Service (1998), in an inventory of Kentucky mining permits issued pursuant to the Surface Mining Control and Reclamation Act report that the Department for Surface Mining Reclamation authorized impacts to 354 miles of streams during the permitting period of April 1986 through July 1995. This included the authorization of placement of overburden in 180 miles of streams, and impacts to an additional 152 miles of streams between valley fills and the downstream sediment retention structures.

2.0 BACKGROUND

EPA Region 4 staff participated in meetings with EPA Region 3, U.S. Fish and Wildlife Service, U.S. Office of Surface Mining, West Virginia Department of Environmental Protection, the Kentucky Division of Water, the Kentucky Department of Fish and Wildlife Resources, and the U.S. Army Corps of Engineers to discuss the environmental impacts associated with mountaintop mining operations. These agencies are currently collaborating to develop an Environmental Impact Statement (EIS) relative to mountaintop mining practices in the Central Appalachian Ecoregion.

In response to ecological concerns and a lack of available information, the EPA Region 4, Water Management Division requested that the EPA Region 4 Science and Ecosystem Support Division evaluate the ecological health of streams associated with mountaintop mining activities.

3.0 STUDY AREA

The study area is located in the Central Appalachian Ecoregion of eastern Kentucky. This area, referred to as the Eastern Coalfield, contains rich deposits of bituminous coal. Stretching from the Appalachian Mountains westward across the Cumberland Plateau, the Eastern Coalfield encompasses much of eastern Kentucky. The Central Appalachian Ecoregion is primarily a rugged plateau composed of sandstone, shale, conglomerate, and coal vegetated by a mixed mesophytic forest. The rugged terrain, cool climate, and infertile soils limit agriculture in this region.

Using land use and cover type information on permitted mining sites, Kentucky orthoquad maps, and information from the Kentucky Division of Water (KDOW), watersheds were selected in areas of active mountaintop mining or recently closed mines. Eight study watersheds were selected, ranging in size from approximately 2 to16 square miles (Figure 1, Table 1). Attempts were made to avoid locating study watersheds in the vicinity of residential areas or permitted municipal/industrial (non-mining) discharges. As a result, only one station (Lost Creek, Station 9) had possible influences from straight pipes (direct discharges of untreated sewage from private residences) and a permitted figure 1

discharge. In addition, a permitted discharge (Perry County school) was located on Sixteen Mile Creek, a tributary to Lost Creek approximately 4.2 miles upstream of Station 9. All stream stations in mined areas were located downstream of the sediment retention ponds that were constructed as part of the mining process. The selected watersheds were classified in the following categories relative to mountaintop mining operations: inactive (old mining), active/inactive, active/reclaimed, and unmined (forested reference) watersheds (Table 1).

Table 1. Stream sampling locations, Eastern Kentucky. May 1-4, 2000.

Stream	Station	Locale	Latitude/ Longitude	County	Drainage area (sq. mi)	Mining Status
Long Fork	1	Buckhorn Cr. Road	37 26.78461 83 11.2066	Breathitt	8.105	active / inactive
Buffalo Creek	3	Fourseam Road	37 13.5054 83 10.3722	Perry	2.755	inactive
Laurel Fork	4	Upper Laurel Fork Road	37 26.4033 83 12.46167	Breathitt/ Perry	3.735	active / inactive
Fugate Branch	5	Fugate Fork Road	37 27.55833 83 14.22333	Breathitt	2.661	active / inactive
Sims Fork	6	Sims Fork Road	36 50.51167 83 36.38667	Bell	6.323	active / reclaimed
Spring Fork/ Quicksand Creek	7	near confluence with Hughes Creek	37 32.905 83 03.815	Breathitt	12.007	active / inactive
Lost Creek	9	SR 1446	37 23.78 83 16.013	Perry	16.858	active / inactive
Lick Branch	14	Cyprus AMAX WMA	37 23.275 83 08.31	Knott/ Perry	3.212	active / inactive
Clemons Fork (Ref)	10	Robinson Forest	37 27.97667 83 09.12833	Breathitt	5.016	unmined
Coles Fork (Ref)	11	Robinson Forest, Buckhorn Ck. Road	37 27.8522 83 07.81434	Knott/ Breathitt	6.115	unmined
Big Double Cr. (Ref)	12	FR 1501	37 06.050 83 35.51	Clay	3.716	unmined
Sugar Cr. (Ref)	13	Redbird WMA	37 07.576 83 32.446	Leslie/ Clay	4.421	unmined

Ref - reference stream

Four reference watersheds were selected in the Robinson Forest and the Redbird WMA (Table 1, Figure 1). Reference watersheds were selected based on the absence of mining activity, proximity to test sites, similar stream order, and recommendations by the KDOW.

4.0 STUDY METHODS

Rapid Bioassessment Protocol III (RBP III) developed by EPA (Plafkin et al. 1989, Barbour et al. 1999) was used to evaluate impacts to these streams. Included in the RBP III are measures of *in situ* water quality and evaluations of the physical habitat which indicate the streams' chemical and physical status. The benthic macroinvertebrate community is the indicator of biological condition. Substrate size, one of the most important determinants of habitat for fish and macroinvertebrates in streams, was determined using EPA Environmental Monitoring and Assessment Program (EMAP) protocols (Kaufmann and Robison 1998, Kaufmann et al. 1999). The substrate characterization was used to evaluate differences in stream bed composition between reference and test sites. Study methods are described below.

4.1 *In Situ* Water Quality

In situ water quality measurements included instantaneous measurements of pH, conductivity, water temperature, and dissolved oxygen. These measurements serve to identify water quality conditions which may affect aquatic life. *In situ* water quality measurements were made prior to collection of macroinvertebrates and habitat evaluations. Hydrolab® multi-parameter field instruments, calibrated prior to daily use, were positioned at approximately 0.5 feet in the water column in an undisturbed area of the study station. All *in situ* water quality measurements were recorded in the field log along with appropriate station information (station number, date, time).
At the end of each sampling day, field instruments used to measure *in situ* water quality were checked for calibration. Results of both pre- and post- sampling instrument calibration were recorded in the field log.

4.2 Macroinvertebrate Sample Collection

Methods used in this study (Plafkin et al. 1989, Barbour et al. 1999, U.S. EPA 2000a) evaluate the status of the benthic macroinvertebrate community. Due to their limited mobility and relatively long life span, benthic macroinvertebrates integrate and reflect water quality effects over time and are excellent indicators of stress in aquatic systems. Rapid Bioassessment Protocol III (RBP III) requires the most intense level of effort of the protocols, followed by identifying macroinvertebrates to at least genus level. Benthic macroinvertebrates were collected from multiple habitats as follows:

riffles - 3 "kicks" in the faster current and 3 "kicks" in the slower current with a standard D-frame biological dip net (800 X 900 μm mesh),
snags/woody debris - 5-6 pieces (~1' length) washed in sieve bucket or standard D-frame biological dip net,
leaf packs - equivalent to one half dip net,
undercut banks - 6 "jabs" with standard D-frame biological dip net, and
bottom substrate - 3 sweeps (disturb sediment to 3 cm depth).

Benthic macroinvertebrate samples were stored in plastic, one quart containers in ethanol (90%). Sample containers were labeled both inside and outside with labels containing the following information: station number, stream name, date and time of collection, and sample type. Samples were checked for adequate preservation at the end of the daily sampling and secured in locked field vehicles until returned to the laboratory where they were sorted under lighted magnification, and then identified and enumerated with the aid of microscopy.

Staff of the KDOW have developed collection methods, tentative scoring criteria for core metrics, and a tentative scoring index referred to as the Macroinvertebrate Bioassessment Index (MBI), for small, headwater streams (1^{st} - 2^{nd} order) in eastern Kentucky (Pond and McMurray 2000). These scoring criteria were developed based on sampling of 42 sites (25 reference and 17 test) scattered throughout the Central and Southwestern Appalachians of Kentucky. Reference streams were located in highly forested, undisturbed areas, whereas test sites ranged from slightly to severely impacted by mining, logging, and residential development. The core metrics used in this index represent four major measures of benthic community health:

1) Richness -- Taxa Richness, EPT Index
2) Composition -- %Ephemeroptera, %Chironomidae + Oligochaeta
3) Tolerance -- Biotic Index, and
4) Habit -- % Clingers.

In discussions prior to this study, biologists from KDOW and EPA Region 4 determined that sampling methods utilized by both agencies were similar both in extent and the approach used to select habitats to be sampled. In order to provide data that are consistent with and complimentary to those of KDOW, riffle kick samples were kept separate from the composite sample for other habitats during sampling and identification. KDOW uses this approach to evaluate the relationship between sediment and biota in productive riffle habitats. This differs from the RBP III protocol and usual EPA Region 4 sampling methods. For data evaluation, the percent metrics (Ephemeroptera, Clingers, Chironomidae + Oligochaeta) and biotic index were calculated from riffle samples only, while taxa richness and EPT index were calculated from both riffle and multihabitat samples combined.

4.3 Habitat Evaluation

Physical habitat quality is a major determinant of biological diversity of stream benthic macroinvertebrate communities. Habitat evaluation results, when compared to reference sites, identify degraded conditions and the severity of such degradation. The High Gradient Habitat Evaluation Form (Barbour et al. 1999) was utilized during this study. Parameters assessed as part of the habitat evaluation include epifaunal substrate, embeddedness, velocity/depth regime, sediment deposition, channel characteristics, bank stability, vegetative cover, and riparian zone integrity.

4.4 Substrate Characterization

Substrate characteristics are important determinants of habitat for fish and macroinvertebrates in streams (Kaufmann and Robison 1998, Kaufmann et al. 1999), and are often sensitive indicators of anthropogenic impacts on streams (Minshall et al 1985). Substrate size characterization was used to evaluate reference versus test sites. Cobble-sized substrate provides the greatest amount of usable habitat to benthic macroinvertebrates, while smaller sized substrate offers reduced habitat for colonization (Green et al. 2000).

Substrate size characterization was performed using EMAP protocols (Kaufmann and Robison 1998, Kaufman et al. 1999). Eleven transects were assessed in each 100 meter reach. The middle transect was located in the riffle where the biological sample was collected. Five transects were located upstream of the middle transect and five downstream of the middle transect. Transects were spaced at 10 meter intervals. Five substrate particles (e.g., cobble, sand, gravel, etc.) selected at evenly spaced intervals across each transect (left, left middle, middle, right middle, and right) were measured (to the nearest millimeter), recorded, and classified. A total of 55 particle measurements were made at each station.

Particle measurements were used to determine the proportion of bedrock, boulder, cobble, coarse gravel, fine gravel, and sand and fines present in the reach, according to Wentworth size classes as described in Wolman (1954). Particles with diameter less than 2 mm were differentiated into specific sand-sized fractions (e.g., 0.125, 0.250, 0.500, 1.00 mm) with the aid of a waterproof "sand card" or identified as silt/clay (<0.062 mm) (Pruitt et al. 1999). The 55 particle measurements were also used to determine the mean particle size in the reach. Since the transects were evenly spaced, the riffle and pool habitat within the reach was sampled in proportion to their presence in the reach. For example, if the 100 meter reach was 20% pool and 80% riffle, then the measurements generally occurred 20% of the time in the pools and 80% of the time in riffles. Bankfull depth, thalweg (the location of the deepest part of the channel), slope, and wetted width were also recorded for each transect. Bankfull depth was estimated by identifying field indicators of bankfull stage (e.g., the top of well-established point bars, vegetation, and/or lichen lines, etc.). Thalweg, slope, and wetted width were measured directly.

5.0 QUALITY ASSURANCE/QUALITY CONTROL

Field and laboratory methods utilized on this project followed EPA approved methodology (Plafkin et al. 1989, Barbour et al. 1999, U.S. EPA 2000a, U.S. EPA 2000b). To provide an indication of field and laboratory precision, duplicate macroinvertebrate samples were collected at two of the 12 sampling sites as determined by the field team leader.

Field instruments utilized during the *in situ* water quality studies were calibrated before and after daily field sampling according to manufacturer's instructions and U.S. EPA (2000b). Calibration results were recorded in the field log book and signed by the project investigator.

6.0 RESULTS AND DISCUSSION

6.1 *In Situ* Water Quality

In situ water quality measurements (pH, conductivity, water temperature, and dissolved oxygen) were collected at each of the 12 study sites (Table 2, Appendix A). The most noticeable *in situ* water quality parameter was elevated conductivity values observed at watersheds associated with MTM/VF operations. EPA Region 3 reported similar findings in recent studies of watersheds in West Virginia associated with mountaintop mining operations (Green et al. 2000). Conductivity values at the test sites ranged from 420 to 1690 µmhos/cm with an average of 994 µmhos/cm (Table 2). When compared to the range (29.9 - 65.8 µmhos/cm) and mean (46.75 µmhos/cm) at the reference watersheds, conductivity at the test sites was 21 times higher.

Table 2. *In situ* water quality measurements, Eastern Kentucky. May 1-4, 2000.

Station #	Stream	Date	Time	D.O. mg/L	Temp. °C	pH Units	Cond. µmhos/cm
1	Long Fork	05/02/00	1300	9.34	15.16	8.08	1310
3	Buffalo Creek	05/03/00	1500	8.44	18.18	8.01	784
4	Laurel Fork	05/03/00	0915	9.54	13.66	7.64	1550
5	Fugate Branch	05/02/00	1305	9.58	15.00	8.19	836
6	Sims Fork	05/03/00	1500	8.52	18.57	8.14	420
7	Spring Fk/Quicksand Cr.	05/02/00	1000	9.17	15.01	7.15	480
9	Lost Creek	05/02/00	1500	9.69	15.97	7.99	881
14	Lick Branch	05/04/00	1005	8.92	16.33	8.16	1690
10 REF	Clemons Fork	05/02/00	1500	9.50	15.40	7.08	65.8
11 REF	Coles Fork	05/02/00	1015	9.44	13.00	7.13	40.6
12 REF	Big Double Creek	05/03/00	1300	9.13	14.30	7.32	50.7
13 REF	Sugar Creek	05/03/00	1000	9.60	12.28	7.42	29.9

REF - reference watershed

The range of observed pH values (Table 2) at watersheds associated with mountaintop mining operations (7.15 to 8.19) was higher than that of the reference watersheds (7.08 to 7.42). This finding is consistent with that observed in EPA Region 3 studies where mined areas exhibited higher pH (Green et al. 2000). Only one test site, Station 7, had a pH that was within the range of pH values observed at the reference watersheds; all other test sites exceeded a pH of 7.6.

In situ water temperature was generally higher at the test sites than at the reference sites (Table 2; Appendix A). Water temperature measurements were made in the morning, midday, or afternoon. Three morning (9:00 - 10:00 a.m.) measurements of water temperature at the test sites ranged from 13.66 to 16.33 ºC, while reference sites were 12.28 and 13.00 ºC for the same period (Table 2).

Midday (1:00 p.m.) water temperatures at two test sites were 15.16 and 15.00 ºC, while midday water temperature measured at one of the reference sites was 14.30 ºC. Afternoon (3 p.m.) measurements of water temperature at three of the test sites ranged from 15.97 to 18.57 ºC while measurement of water temperature at a reference site during this same period was 15.40 ºC.

Dissolved oxygen values at the test sites ranged from 8.44 to 9.69 mg/L while reference sites ranged from 9.13 to 9.60 mg/L (Table 2). As illustrated by the box and whisker plot (Appendix A), dissolved oxygen values at the test sites exhibited a greater variation over the morning through afternoon period than was observed at the reference sites.

6.2 Benthic Macroinvertebrates

Benthic macroinvertebrates were identified to genus level (Appendix B). As discussed previously, the choice of core metrics was consistent with Kentucky's Macroinvertebrate Bioassessment Index (MBI) for Headwater Streams of the Eastern Coalfield Region of Kentucky (Pond and McMurray 2000 draft). This study adopted Kentucky's genus level Tentative Scoring Criteria for MBI Metrics (Table 3) and the Tentative MBI and Habitat Narrative Scoring Criteria (Table 4).

Table 3. Genus level tentative scoring criteria for MBI metrics from Pond and McMurray (2000, unpublished).

METRIC	SCORE		
	6	3	0
Taxa Richness	>40	20 - 39	<20
EPT Index	>22	11 - 22	<11
Biotic Index	<2.68	2.68 - 4.50	>4.51
% Clingers	>50	25 - 50	<25
% Ephemeroptera	>43	22 - 43	<22
% Chironomidae + Oligochaeta	<3.0	3.1 - 7.4	>7.4

Table 4. Genus level tentative MBI and habitat narrative scoring criteria (genus level) from Pond and McMurray (2000 unpublished).

Metric	Narrative Scoring Criteria			
	Excellent	Good	Fair	Poor
MBI	33 - 36	27 - 30	18 - 24	0 - 15
Habitat score	175 - 200	161 - 174	147 - 160	0 - 146

To provide a unitless and weighted scoring method, the actual result for each metric (Table 5) was given a score of 6, 3, or 0 (from Table 3). The metric scores were then summed to yield the MBI (Table 5). Habitat and MBI narrative rankings (excellent, good, fair, poor) were derived from Table 4.

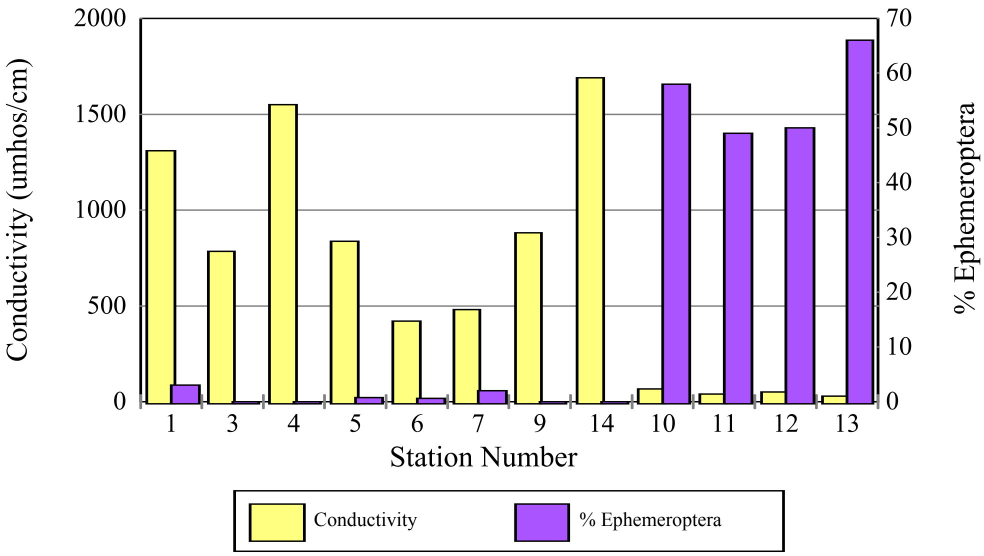
Table 5. Metric results, tentative scores, and final index (MBI) scores, Eastern Kentucky. May 1-4, 2000.

Station	METRIC RESULTS AND TENTATIVE SCORES						HABITAT		MBI	
	Taxa Richness	EPT Index	Biotic Index	% Clingers	% Ephem	% Chir + Olig	Score	Rank	Score	Rank
1	34	12	4.19	54	3	26	173	good	15	poor
3	24	4	5.56	3	0	92	166	good	3	poor
4	31	9	5.46	13	0	81	128	poor	3	poor
5	42	11	3.74	28	0.77	50	138	poor	15	poor
6	28	15	4.42	22	0.57	54	144	poor	9	poor
7	33	9	5.52	3	2	83	131	poor	3	poor
9	31	4	4.86	7	0	85	171	good	3	poor
14	25	7	4.92	21	0	38	149	fair	3	poor
10 (ref)	46	21	3.23	59	58	2	167	good	30	good
11 (ref)	38	16	3.23	46	49	3	174	good	24	fair
12 (ref)	41	24	2.97	29	50	3	181	excellent	30	good
13 (ref)	47	24	2.74	59	66	4	181	excellent	30	good

(ref) - reference watershed

Of the individual core metrics, % Ephemeroptera (Table 5) revealed the greatest sensitivity to environmental perturbation. A composition measure, % Ephemeroptera, represents the numerical abundance of mayflies as a percentage of the total individuals collected at a site. Past studies by EPA Region 4 in the Martha Oil Field region of Kentucky (U.S. EPA 1989), Hurricane Creek in Alabama (U.S. EPA 2000c) and recent studies in West Virginia by EPA Region 3 (Green et al. 2000) have identified a strong correlation between elevated conductivity and low numbers of mayflies in streams where mining operations exist. Figure 2 depicts the inverse relationship between elevated conductivity and absence or paucity of Ephemeroptera noted at test sites in the present study. Mayflies, along with the stoneflies (Plecoptera) and caddisflies (Trichoptera) are generally considered pollution-sensitive macroinvertebrates. Mayflies were absent in samples collected at half (4) of the test sites. The remaining four test sites had % Ephemeroptera results ranging from only 0.57% to 3.0% (Table 5). Conversely, reference sites had % Ephemeroptera ranging from 49% to 66%.

Figure 2. Conductivity and % Ephemeroptera at reference and test sites.



Although mayflies were drastically reduced in streams associated with mountaintop mining operations, pollution-sensitive stoneflies (Plecoptera) and caddisflies (Trichoptera) were collected at those locations. The core metric EPT Index, a summation of taxa in the pollution-sensitive Ephemeroptera, Plecoptera, and Trichoptera, is a richness measure specifically focusing on the presence/absence of pollution-sensitive fauna. Although effects were not as severe as those observed in the mayfly fauna, comparison of the range of the EPT Index at the test sites (4 to 15) with that of the reference sites (16 to 24) indicated the loss of some stoneflies and caddisflies at the test sites (Table 5). The core metric EPT Index has been identified in past studies and in the literature as one of the most discriminatory metrics (Barbour et al. 1996; Wallace et al. 1996).

A third metric, Taxa Richness, is the sum of benthic macroinvertebrate species collected from a given stream location and represents diversity. Taxa Richness values revealed a reduction in the number of benthic macroinvertebrate species in test watersheds when compared to reference watersheds. For example, Taxa Richness at test sites ranged from 24 to 42 while Taxa Richness for the reference watersheds ranged from 38 to 47 (Table 5). The previously identified reduction in pollution-sensitive EPT fauna contributed to the decrease in Taxa Richness at the test sites.

The Biotic Index, derived from Hilsenhoff (1987), is calculated by applying tolerance values to collected individuals to derive a community-based estimate of overall pollution at a given site. The tolerance values of various taxa range from 0-10, with 0 being the most pollution intolerant and 10 being the most pollution tolerant taxa. The presence of sensitive (intolerant) organisms would result in a low Biotic Index value, whereas, the presence of more tolerant organisms would result in a higher value. Biotic Indices at the test sites were higher (3.74 to 5.56) than those at the reference watersheds (2.74 to 3.23).

Whereas the core metrics % Ephemeroptera and EPT Index focus on fauna sensitive to pollution, the % Chironomidae + Oligochaeta metric focuses on pollution-tolerant organisms. A composition measure, % Chironomidae + Oligochaeta represents the numerical abundance of pollution-tolerant midges

(Chironomidae) and worms (Oligochaeta) as a percentage of the total individuals collected at a site. In a healthy, balanced benthic macroinvertebrate community, percentages of pollution-tolerant organisms are minimal. This was not the case in watersheds associated with mountaintop mining operations. Percent Chironomidae + Oligochaeta at the test sites ranged from 26 to 92 (Table 5) with a mean of over 63%. Conversely, % Chironomidae + Oligochaeta for reference watersheds range from 2% to 4%.

Percent Clingers, the final core metric utilized in the derivation of the MBI, represents the numerical abundance of organisms (percentage of the total individuals) that are morphologically adapted for attachment to stream substrates in generally faster currents such as riffles. Percent clingers for watersheds associated with mountaintop mining operations ranged from 3 to 54 (Table 5) with a mean of 19; reference watersheds ranged from 29 to 59 with a mean of 48.

The MBI score, derived from all of the core metrics, ranged from 3 to 30. MBI scores at the reference sites ranged from 24 to 30 with three of the sites ranking in the "good" category and one site at the upper limit of the "fair" category (Table 5). All test sites associated with mountaintop mining ranked in the "poor" category based on the MBI results .

The discriminatory ability of the six core metrics is apparent in the box and whisker plots in Appendix B. These metrics exhibited no overlap in distributions in test versus reference watersheds, thus supporting their choice as strong discriminators of impaired and reference conditions and illustrating the severity of impairment in the benthic macroinvertebrate communities of watersheds associated with mountain top mining operations.

6.3 Habitat Evaluation

Habitat evaluation scores for watersheds associated with mountaintop mining ranged from 131 to 173 with a mean of 150, while reference sites ranged from 167 to 181 with a mean of 175 (Table 5, Appendix C). Four of the eight test sites had habitat evaluation scores in the "poor" category based on the KDOW criteria (Table 4). Habitat degradation, evidenced by the "poor" habitat characterization at these four test sites, was related to a decrease in the velocity/depth regime (habitat), moderate to severe embeddedness, and moderate to heavy sediment deposition. These test sites with "poor" habitat evaluation scores (Stations 4,5,6, and 7) also had MBI rankings in the "poor" category (Table 5). However, test sites with "good" habitat evaluation scores (Stations 1, 3, and 9) also had MBI rankings in the "poor" category. This suggests that factors other than habitat degradation may be involved in impairment of the benthic community at some locations. Habitat evaluation scores at two of the reference watersheds were in the "excellent" category while two were in the "good" category. In contrast to the test sites, the reference watersheds had MBI rankings in the "good" category with the exception of Station 11 which had an MBI ranking at the upper limit (24) of the "fair" category.

6.4 Substrate Size Characterization

Substrate size and composition were measured at eight of the 12 sampling sites. Following the sample design and analysis employed by EPA Region 3 (Green et al. 2000, Kaufmann et al. 1999, Bain et al. 1985), numeric values (e.g. Class Score, Table 6) were assigned to the substrate size classes. These class scores are proportional to the logarithm of the midpoint diameter of each size class (Kaufman et al. 1999).

Table 6. Substrate size classes and class scores, Kentucky Mountaintop Mining, May 2000.

Substrate Size Class	Size (mm)	Class Score
Bedrock	>4000	6
Boulder	>250 - 4000	5
Cobble	>64 - 250	4
Coarse Gravel	>16 - 64	3.5
Fine Gravel	>2 - 16	2.5
Sand	>0.06 - 2	2
Fines	<0.06	1

A mean substrate size class score (of the numerically transformed size class) was calculated for the sampling reach (Table 7). The reach level mean substrate size in millimeters was then calculated using the substrate size class score (Kaufmann et al. 1999). The median substrate size class or D_{50} was taken from cumulative % distribution graphs presented in Appendix D. The reach level percentages of sands and fines (≤2mm diameter) were derived from the frequency of particles in these two size classes divided by the 55 total particle measurements. For example, if five of the measurements in the reach were classified as sand or fines, then the % of the substrate less than or equal to 2 mm would be 5/55*100 or approximately 9%.

Table 7. Summary of substrate size and composition data, Kentucky Mountaintop Mining, May 2000.

Substrate Parameter:	Reference (n=3)	Mined/Filled (n=5)
Mean substrate size class score and standard deviation	3.91 (0.52)	2.91 (0.30)
Calculated mean substrate size (mm) and substrate classification	141 (Cobble)	13 (Fine Gravel)
Median substrate size class or D_{50} (mm) and substrate classification	153 (Cobble)	21 (Coarse Gravel)
% substrate size ≤2 mm (sand and fines) and standard deviation	22.4 (6.4)	30.6 (9.1)

The substrate size data indicate that the mean substrate size class scores and the mean calculated substrate particle sizes were smaller in the mined sites than in the unmined sites (Table 7). The median substrate size class or D_{50} and the calculated mean substrate size yielded similar results (Tables 7 & 8).

The calculated mean substrate size and D_{50} of the reference sites included bed surface material that was generally characterized as cobble. The average percent substrate size $\leq$2mm (sands and fines) was 22.4 at reference sites and 30.6 at test sites. Substrate characterization metrics for individual stations are summarized in Table 8.

Table 8. Summary of substrate characterization metrics at sampling sites. May 2000.

Stream	Station	Median substrate size or D_{50} (mm)	Mean substrate size class score	Calculated mean substrate size (mm)	% $\leq$ 2mm (sands and fines)
Long Fork	1	11	2.57	5	36.4
Laurel Fork	4	13	2.65	6	40.0
Fugate Branch	5	30	3.31	26	21.8
Spring Fork/ Quicksand Cr.	7	35	3.04	14	34.6
Clemons Fork (ref)	10	350	4.43	295	21.8
Coles Fork (ref)	11	60	3.89	96	29.1
Big Double Cr. (ref)	12	50	3.40	31	16.3
Lick Branch	14	18	2.96	12	20.0

The median particle size at reference sites was characterized as large cobble whereas the median particle size at mined sites was characterized as coarse gravel.

7.0 Associations Between Benthic Macroinvertebrate Metrics and Physical/Chemical Variables

The physical and chemical conditions of the streams were described using direct measurements of *in situ* water quality, physical habitat, and substrate size and composition. Associations between the benthic metrics and conductivity, total habitat scores, sediment deposition scores, and percent sand and fines were explored with correlation analyses (Table 9) similar to methods employed by Region 3 (Green et al. 2000).

Table 9. Correlations between benthic macroinvertebrate metrics and physical/chemical variables. Values in bold are statistically significant at the p≤0.05 level.

r - correlation coefficient (p value)	Conductivity (µS/cm)	Habitat Score	Sediment Deposition Score	% ≤2mm (% sand and fines)
MBI	-0.71 **(0.009)**	0.60 **(0.038)**	0.47 (0.121)	-0.46 (0.251)
Taxa Richness	-0.64 **(0.024)**	0.38 (0.226)	0.23 (0.480)	-0.39 (0.337)
EPT	-0.72 **(0.008)**	0.47 (0.121)	0.38 (0.217)	-0.52 (0.188)
BI	0.68 **(0.016)**	-0.63 **(0.027)**	-0.46 (0.137)	0.63 (0.091)
% Chironomidae & Oligocheate	0.52 (0.085)	-0.60 **(0.038)**	-0.41 (0.184)	0.60 (0.119)
% Ephemeroptera	-0.77 **(0.003)**	0.65 **(0.022)**	0.53 (0.075)	-0.47 (0.233)
% Clingers	-0.38 (0.228)	0.55 (0.063)	0.35 (0.258)	-0.17 (0.685)
Conductivity		-0.48 (0.115)	-0.590 **(0.044)**	0.38 (0.354)
n=8 for % ≤ 2mm pairs, n=12 for all other pairs				

Generally, the benthic metrics responded as expected to the potential stressors. The MBI, Taxa richness, EPT, % Ephemeroptera, and % Clingers all decreased with increasing conductivity and increasing % sands and fines. While the metrics BI and % Chironomidae and Oligochaeta, identifying a lack of sensitive species and the presence of more tolerant species, was positively correlated with conductivity and % sands and fines.

The strong negative correlation between conductivity and % Ephemeroptera reaffirms the inverse relationship shown in Figure 2 (i.e., where conductivity is elevated, there is an absence or paucity of Ephemeroptera).

8.0 CONCLUSIONS

Measureable differences in pH, temperature, conductivity, and dissolved oxygen were observed between reference and test sites. The most noticeable difference was elevated conductivity observed at the watersheds associated with mountaintop mining operations. Average conductivity at the test sites was 21 times higher than at reference sites, suggesting conductivity as either a route by which impairment occurred in mined areas, or a surrogate for other factors that were not measured. A more comprehensive evaluation of stream water chemistry may provide information the would better explain stream impacts.

Habitat scores were correlated to several measures of diversity and dominance of key groups of macroinvertebrates. Habitat scores were generally lower at sampling locations downstream of test areas than at reference sites. In particular, active mining sites and recently mined sites received very poor sediment deposition and embeddedness scores (individual parameters within the RBP habitat evaluation), indicating increased sedimentation in streams associated with mining activity. Substrate characterization data also indicated that substrate particle sizes were smaller in the mined sites than in the unmined sites.

The core metrics used in this study proved to be strong discriminators of impaired and reference conditions. These metrics illustrated the severity of impairment in the benthic macroinvertebrate communities of watersheds associated with mountain top mining operations. Of the individual core metrics, % Ephemeroptera revealed the greatest sensitivity to environmental perturbation. A strong inverse relationship was apparent between elevated conductivity and absence or paucity of Ephemeroptera (mayflies) at the test sites. Mayflies were either absent or comprised < 3.0 % of the benthic community at the test sites. Conversely, reference sites had % Ephemeroptera ranging from 49% to 66%. Other metrics sensitive to perturbations, including EPT Index, Taxa Richness, and % Clingers, were generally lower at test sites than at reference sites. The biotic index and % Chironomidae + Oligochaete were higher at test sites, indicating the absence of sensitive species and the presence of more tolerant benthic organisms. These study results confirm that benthic macroinvertebrate communities at all the test sites were severely impaired. Specific responses of the benthic macroinvertebrate communities to mountaintop mining operations are expressed through a decrease in diversity, a reduction or absence of pollution-sensitive species (especially mayflies), and an increase in pollution-tolerant species.

Macroinvertebrate, habitat, and *in situ* water quality data collected during this study document significant differences between streams located in reference watersheds and streams located in watersheds with mountaintop mining/valley fill operations (test sites). Mining related sites generally had higher conductivity, greater sediment deposition, smaller substrate particle sizes, and a decrease in pollution sensitive macroinvertebrates with an associated decrease in taxa diversity compared to reference sites.

Recognizing that aquatic resources of a stream ecosystem are a reflection of its surrounding landscape and land uses (Minshall et al 1985), concerns arise when rugged, steep terrains covered by deciduous forest typical of the Central Appalachians are replaced by gently rolling hills and pastures. Non-woody organic matter, originating from densely-forested streams has been identified as the major energy base of aquatic ecosystems (Vannote et al. 1980, Cummins 1980, Merritt et al. 1984). Deforestation, an environmental liability associated with mountaintop mining operations, would naturally affect the organic inputs to the energy budgets of aquatic ecosystems. Disruptions in the biological processes of first- and second-order streams impact not only aquatic life within the stream, but also the functions that aquatic life contribute to downstream aquatic systems in the form of nutrient cycling, food web dynamics, and species diversity (Cummins 1980, Merritt et al. 1984).

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APPENDIX A:

Box and Whisker Plots

APPENDIX B:

Benthic Macroinvertebrate Identifications

APPENDIX C:

Habitat Evaluation Forms

APPENDIX D:

Substrate Characterization Data and Cumulative Distribution Graphs

Water Body : Long Fork
Date Placed :
Date Collected : 5/2/00
Collector : Maudsley, Ackerman
sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
sample #: KYM-01R	Sample #:	Sample #:	Bottom:

	ORGANISMS	REPLIC 1 Count	REPLIC 1 #M»	REPLIC 2 Count	REPLIC 2 #M»	REPLIC 3 Count	REPLIC 3 #M»	COMPOSITE Count	COMPOSITE #M»
DIPTERA	*Bezzia* sp.	1	1					1	
DIPTERA	*Conchapelopia* sp.	1	1					1	
DIPTERA	*Orthocladius* sp.	1	1					1	
DIPTERA	*Cricotopus bicinctus*	1	1					1	
DIPTERA	Chaetocladius sp.	1	1					1	
DIPTERA	*Parametriocnemus* sp.	1	1					1	
OLIGOCHAETA	~~Tubificidae sp.~~	3	3					3	
EPHEMEROPTERA	*Epeorus* sp.	1	1					1	
PLECOPTERA	*Amphinemura* sp.	6	6					6	
PLECOPTERA	~~Perlesta sp. (very immature)~~	13	13					13	
PLECOPTERA	*Isoperla* sp.	3	3					3	
PLECOPTEKA	*Haplaperla* sp.	1	1					1	
TRICHOPTERA	~~Rhyacophila sp.~~	1	1					1	
TRICHOPTERA	~~Chimarra sp.~~	1	1					1	
								0	
								0	
								0	
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								0	
								0	
	TOTALS:	35	35	0	0	0	0	35	0
	# OF TAXA:	14		0		0		14	
	DIVERSITY INDEX:		3.04		0		0		3.04

MACROINVERTEBRATE
BIOLOGY DATA SHEET

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Long Fork
Date Placed :
Date Collected : 5/2/00
Collector : Maudsley, Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-01R	Sample #:	Sample #:	Bottom:

CLASS I SPECIES.	4	28.57%	CLASS I INDIV.	4	11.43%
CLASS II SPECIES	0	0%	CLASS II INDIV.	0	0%
CLASS III SPECIES:	1	7.14%	CLASS III INDIV:	6	17.14%
CLASS IV SPECIES	0	0%	CLASS IV INDIV.	0	0%
CLASS V SPECIES	9	64.29%	CLASS V INDIV.	25	71.43%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	14	3	1
EPT INDEX	7	3	5
% CONTRIBUTION OF DOMINANT TAXON	37.14 %	1	1
FLORIDA INDEX	8	5	1
% DIPTERA	17.14 %	3	3
% COLLECTOR-FILTERERS	2.86 %	1	1
% SHREDDERS	20 %	3	3
% CRUSTACEANS AND MOLLUSKS	0 %	1	---
# CRUSTACEANS AND MOLLUSKS	0	1	---
SCORES		21	15
EVALUATION		Moderate Impairment	Moderate Impairment

a

COMMUNITY DISTRIBUTION REPORT

Water Body : Long Fork
Dace Placed :
Date Collected : 5/2/00
Collector : Maudsley, Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs. :	Grabs :	Grabs : 1
Sample #: KYM-01R	sample #:	Sample #:	Bottom:

	Total	% of Sample
PLECOPTERA	13	37.14%
PLECOPTERA	6	17.14%
OLIGOCHAETA	3	8.57%
PLECOPTERA	3	8.57%
DIPTERA	1	2.86%
DIPTERA	I	2.86%
DIPTERA	1	2.86%
EPHEMEROPTERA	1	2.86%
DIPTERA	1	2.86%
DIPTERA	I	2.86%
DIPTERA	1	2.86%
PLECOPTERA	1	2.86%
TRICHOPTERA	1	2.86%
TRICHOPTERA	1	2.86%

EQUITABILITY (Diversity due to species composition): 0.86

PERCENT CONTRIBUTION OF DOMINANT TAXON: Perlesta sp. (very immature) 13 37.14 %

FUNCTIONAL FEEDING GROUPS

Unknown............	24	68.57%
Shredder...........	7	20%
Collector Gatherer.	2	5.71%
Predator...	1	2.86%
Collector Filterer.	1	2.86%
Scraper............	0	00%
Piercer............	0	00%

Water Body : **Long Fork**
Date Placed :
Collector : Maudsley/Ackerman
Identified By: Smith/Schultz/Foster
Date Collected : 5/2/00
Sorted By' : **Howard/Berrang**
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-01M	Sample #:	Sample I:	Bottom:

ORGANISMS		REPLIC 1 Count	#M»	REPLIC 2 Count	#M»	REPLIC 3 Count	#M»	COMPOSITE Count	#M»
DIPTERA	*Pilaria sp.*	1	1					1	
DIPTERR	*Simulium sp.*	1	1					1	
DIPTERA	*Hemerodromia sp.*	2	2					2	
DIPTERA	*Larsia* SD.	1	1					1	
DIPTERA	*Conchapelopia sp.*	2	2					a	
DIPTERA	Parachaetocladius sp.	1	1					1	
DIPTERA	*Tvetenia bavarica gp.*	3	3					3	
DIPTERA	*Chaetocladius sp.*	1	1					1	
DIPTERA	*Cricotopus sp.*	1	1					1	
DIPTERA	*Cricotopus bicinctus*	3	3					3	
DIPTERA	*Parametriocnemus sp.*	4	4					4	
DIPTERA	*Cryptochironomus sp.*	1	1					1	
MEGALOPTERA	*Sialis sw.*	1	1					1	
COLEOPTERA	*Dubiraphia sp.*	1	1					1	
ODONATA	~~*Stylurus sp.*~~	1	1					1	
ODONATA	~~*Argia sw.*~~	1	1					1	
ODONATA	*Gomphidae unid.*	4	4					4	
DECAPODA	~~*Astacidae unid.*~~	1	1					1	
OLIGOCHAETA	~~*Limnodrilus sp.*~~	1	1					1	
OLIGOCHAETA	~~*Tubificidae* SD.~~	1	1					1	
PLECOPTERA	~~*Amphinemura* sp.~~	37	37					37	
PLECOPTERR	~~*Perlesta sp. (very* immature)~~	8	8					8	
PLECOPTERA	~~*Isoperla sp.*~~	4	4					4	
FLECOPTERA	~~*Remenus sp.*~~	1	1					1	
TRICHOPTERR	~~*Cheumatopsyche sp.*~~	1	1					1	
TRICHOPTERA	~~*Ironoquia sp.*~~	1	1					1	
TRICHOPTERA	~~*Lepidostoma sp.*~~	1	1					1	
TRICHOPTERA	~~*Hydroptila sp. (small/hard to ID)*~~	1	1					1	
TRICHOPTERA	~~*Chimarra sp.*~~	2	2					2	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
MACROINVERTEBRATE BIOLOGY DATA SHEET	TOTALS:	88	88	0	0	0	0	88	0
	# OF TAXA:	29		0		0		29	
	DIVERSITY INDEX:		3.55		0		0		3.55

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Long Fork
Date Placed. :
Date Collected : 5/2/00
collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-01M	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 5	17.24%	CLASS I INDIV.	: 8	9.09%
CLASS II SPECIES	: 2	6.9%	CLASS II INDIV.:	2	2.2'7%
CLASS III SPECIES:	3	10.34%	CLASS III INDIV:	39	44.32%
CLASS IV SPECIES	: 1	3.45%	CLASS IV INDIV.:	1	1.14%
CLASS V SPECIES	: 18	62.07%	CLASS V INDIV.	: 38	43.18%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	29	5	3
EPT INDEX	9	3	5
% CONTRIBUTION OF DOMINANT TAXON	42.05 %	1	I
FLORIDA INDEX	12	5	3
% DIPTERA	23.86 %	3	3
% COLLECTOR-FILTERERS	4.55 %	3	1
% SBREDDERS	48.86 %	3	3
% CRUSTACEANS AND MOLLUSKS	1.14 %	1	---
# CRUSTACEANS AND MOLLUSKS	1	1	---
SCORES		25	19
EVALUATION		Moderate Impairment	Moderate Impairment

Water Body : Grapevine Creek
Date Placed : Date Collected : 5/4/00
Collectox : Howard/Weldon Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-02R	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	#M»	REPLIC 2 Count	#M»	REPLIC 3 Count	#M»	COMPOSITE Count	#M»
DTPTERA	*Tipula sp.*	1	1					1	
DIPTERA	Psychada *sp.*	2	2					2	
DIPTERA	Natarsia *sP.*	1	1					1	
DIPTERA	*Conchapelopia SP.*	2	2					2	
DIPTERA	*Labrundinia neopilosella*	1	1					1	
DIPTERA	*Parachaetocladius* SD.	1	1					1	
DIPTERA	*Parametriocnemus sp.*	43	43					43	
DIPTERA	*Orthocladius sp.*	67	67					67	
DIPTERA	*Cricotopus 3 spp.?*	71	71					71	
DIPTERA	*Eukiefferiella devonica gp.*	1	1					1	
DIPTERA	*Chironomus sp.*	3	3					3	
DECAPODA	*Astacidae unid.*	1	1					1	
MEGALOPTERA	*Sialis sp.*	1	1					1	
OLIGOCHAETA	*Limnodrilus sp.*	8	8					8	
OLIGOCHAETA	Tubificidae *sp.*	4	4					4	
OLIGOCHAETA	*Lumbriculidae unid.*	2	2					2	
OLIGOCHAETA	*Isochaeta* unidentified	4	4					4	
								0	
								0	
								0	
								0	
								0	
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MACROINVERTEBRATE BIOLOGY DATA SHEET	TOTALS:	213	213	0	0	0	0	213	0
	# OF TAXA:	17		0		0		17	
	DIVERSITY INDEX:		2.44		0		0		2.44

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MACROINVERTEBRATE SUMMARY REPORT

Water Body : Grapevine Creek
Date Placed :
Date Collected : 5/4/00
Collector : Howard/Weldon
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-02R	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 1	5.88%	CLASS I INDIV.	: 1	.47%
CLASS II SPECIES	: 0	0%	CLASS II INDIV.:	0	0%
CLASS III SPECIES:	3	17.65%	CLASS III INDIV:	13	6.1%
CLASS IV SPECIES	: 1	5.88%	CLASS IV INDIV.:	1	.47%
CLASS V SPECIES	: 12	70.59%	CLASS V INDIV.	: 198	92.96%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	17	3	3
EPT INDEX	0	1	1
% CONTRIBETION OF DOMINANT TAXON	33.33 %	3	1
FLORIDA INDEX	2	1	1
% DIPTERA	90.61 %	1	1
% COLLECTOR-FILTERERS	0 %	1	1
% SRREDDERS	.47 %	1	1
% CRUSTACEANS AND MOLLUSKS	.47 %	1	---
# CRUSTACEANS AND MOLLUSKS	1	1	---
SCORES		13	9
EVALUATION		Severe Degradation	Severe Degradation

COMMUNITY DISTRIBUTION REPORT

Water Body : Grapevine Creek
Date Placed : | Date Collected : 5/4/00
Collector : Howard/Weldon | Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster | Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-02R	Sample #:	Sample #:	Bottom:

	Total	% of Sample
DIPTERA	71	33.33%
DIPTERA	67	31.46%
DIPTERA	43	20.19%
OLIGOCHAETA	8	3.76%
OLIGOCHAETA	4	1.88%
OLIGOCHAETA	4	1.88%
DLPTERA	3	1.41%
DIPTERA	2	0.94%
DIPTERA	2	0.94%
OLIGOCHAETA	2	0.94%
DIPTERA	1	0.47%
DECAPODA	1	0.47%
MEGALOPTERA	1	0.47%
DIPTERA	1	0.47%
DIPTERA	1	0.47%
DIPTERA	1	0.47%
DIPTERA	1	0.47%

EQUITABILITY (Diversity due to species composition): 0.41

PERCENT CONTRIBUTION OR DOMINANT TAXON: Cricotopus 3 spp.? 71 33.33 %

FUNCTIONAL FEEDING GROUPS

Unknown............	193	90.61%
collector Gatherer.	14	6.57%
Predator...........	5	2.35%
Shredder...........	1	0.47%
scraper............	0	00%
collector Filterer.	0	00%
Piercer............	0	00%

Water Body : Buffalo Creek
Date Placed : Date Collected : 5/3/00
Collector : Maudsley/Ackerman Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-03R	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	#M»	REPLIC 2 Count	#M»	REPLIC 3 Count	#M»	COMPOSITE Count	#M»
DIPTEILA	*Limnophila sp.*	3	3					3	
DIPTERA	*Conchapelopia sp.*	3	3					3	
DIPTERA	*Chaetocladius sp.*	1	1					1	
DIPTEILA	*Brillia sD.*	2	2					2	
DIPTERA	*Diamesa sp.*	2	2					2	
DIPTERA	*Eukiefferiella claripennis gp.*	1	1					1	
DIPTERA	Eukiefferiella *brevicalca*	3	3					3	
DIPTERA	Eukiefferiella *devonica gp.*	1	1					1	
DIPTERA	*Tvetenia bavarica gp.*	1	1					1	
DIPTERA	*Parametriocnemus sp.*	37	37					37	
DIPTERA	*Cricotopus bicinctus*	21	21					21	
DIPTERA	*Orthocladius sp.*	34	34					34	
DIPTERA	*Polypedilum convictum group*	4	4					4	
OLIGOCHAETA	*Lumbriculus sp.*	59	59					59	
COLEOPTERA	*Optioservus sp.*	3	3					3	
PLECOPTERA	*Allocapnia sp.*	1	1					1	
PLECOPTERA	*Amphinemura sp.*	6	6					6	
TRICHOPTERA	*Cheumatopsyche sp.*	1	1					1	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
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								0	
MACROINVERTEBRATE BIOLOGY DATA SHEET	TOTALS:	183	183	0	0	0	0	183	0
	# OF TAXA:	18		0		0		18	
	DIVERSITY INDEX:		2.86		0		0		2.86

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Buffalo Creek
Date Placed :
Date Collected : 5/3/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-03R	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 2	11.11%	CLASS I INDIV.	: 24	13.11%
CLASS II SPECIES	: 1	5.56%	CLASS II INDIV.:	1	.55%
CLASS III SPECIES:	3	16.67%	CLASS III INDIV:	68	37.16%
CLASS IV SPECIES	: 1	5.56%	CLASS IV INDIV.:	2	1.09%
CLASS V SPECIES	: 11	61.11%	CLASS V INDIV.	: 88	48.09%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	18	3	3
EPT INDEX	3	1	1
% CONTRIBUTION OF DOMINANT TAXON	32.24 %	3	1
FLORIDA INDEX	5	3	1
% DIPTERA	61.75 %	1	1
% COLLECTOR-FILTERERS	.55 %	1	1
% SHREDDERS	18.03 %	3	3
% CRUSTACEANS AND MOLLUSKS	0 %	3	---
# CRUSTACEANS AND MOLLUSKS	0	1	---
SCORES		17	11
EVALUATION		Moderate Impairment	Severs Degradation

COMMUNITY DISTRIBUTION REPORT

Water Body : Buffalo Creek
Date Placed : Date Collected : 5/3/00
Collector : Maudsley/Ackerman Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Facaor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-03R	Sample #:	Sample #:	Bottom:

	Total	% of Sample
OLIGOCHAETA	59	32.24%
DIPTERA	37	20.22%
DIPTERA	34	18.58%
DIPTERA	21	11.48%
PLECOPTERA	6	3.28%
DIPTERA	4	2.19%
DIPTERA	3	I.64%
DIPTERA	3	1.64%
DIPTERA	3	1.64%
COLEOPTERA	3	1.64%
DIPTERA	2	1.09%
DIPTERA	2	1.09%
DIPTERA	1	0.55%
DIPTERA	1	0.55%
DIPTERA	1	0.55%
PLECOPTERA	1	0.55%
DIPTERA	1	0.55%
TRICHOPTERA	1	0.55%

EQUITABILITY (Diversity due to species composition): 0.56

PERCENT CONTRIBUTION OF DOMINANT TAXON: Lumbriculus sp. 59 32.24 %

FUNCTIONAL FEEDING GROUPS

Unknown............	79	43.17%
Collector Gatherer.	67	36.61%
Shredder...........	33	18.03%
Predator...........	3	1.64%
Collector Filterer.	1	0.55%
Scraper............	0	00%
Piercer............	0	00%

Water Body : Buffalo Creek
Date Placed :
Date Collected : 5/3/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-03M	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	REPLIC 1 #M»	REPLIC 2 Count	REPLIC 2 #M»	REPLTC 3 Count	REPLTC 3 #M»	COMPOSITE Count	COMPOSITE #M»
JJIPTERA	*Conchapelopia sp.*	1	1					1	
DIPTERA	*Brillia sp.*	14	4					4	
DIPTERA	*Parametriocnemus sp.*	20	20					20	
DIPTERA	*Cricotopus sp.*	4	4					4	
DIPTERA	*Orthocladius sp.*	15	15					15	
DIPTERA	*Thienemanniella xena*	1	1					1	
DIPTERA	*Chaetocladius sp.*	1	1					1	
DIPTERA	*Limnophyes sp.*	1	1					1	
DIPTERA	*Polypedilum tritum type*	1	1					1	
OLIGOCHAETA	*Lumbriculidae unid.*	2	2					2	
DECAPODA	*Astacidae unid.*	1	1					1	
ODONATA	*Boyeria sD.*	1	1					1	
ODONATA	*Calopteryx sp.*	1	1					1	
EPHEMEROPTERA	*Eurylophella sp.*	1	1					1	
PLECOPTERA	Amphinemura sp.	11	11					11	
TRICHOPTERA	*Cheumatopsyche sp.*	1	1					1	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
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								0	
								0	
								0	
								0	
MACROINVERTEBRATE BIOLOGY DATA SHEET	TOTALS:	66	66	0	0	0	0	'66	0
	# OF TAXA:	16		0		0		16	
	DIVERSITY INDEX:		3		0		0		3

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Buffalo Creek
Date Placed : Date Collected : 5/3/00
Collector : Maudsley/Ackerman Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-03M	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 2	12.5%	CLASS I INDIV.	: 2	3.03%
CLASS II SPECIES	: 2	12.5%	CLASS II INDIV.	: 5	7.58%
CLASS III SPECIES	: 2	12.5%	CLASS III INDIV	: 13	19.7%
CLASS IV SPECIES	: 0	0%	CLASS IV INDIV.	: 0	0%
CLASS V SPECIES	: 10	62.5%	CLASS V INDIV.	: 46	69.7%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	16	3	3
EPT INDEX	3	1	1
% CONTRIBUTION OF DOMINANT TAXON	30.3 %	3	1
FLORIDA INDEX	6	3	1
% DTPTERA	72.73 %	1	1
% COLLECTOR-FILTERERS	1.52 %	1	1
% SHREDDERS	30.3 %	3	3
% CRUSTACEANS AND MOLLUSKS	1.52 %	1	---
# CRUSTACEANS AND MOLLUSKS	1	1	---
SCORES		17	11
EVALUATION		Moderate Impairment	Severe Degradation

COMMUNITY DISTRIBUTION REPORT

Water Body : Buffalo Creek

Date Placed : | Date Collected : 5/3/00

Collector : Maudsley/Ackerman | Sorted By : Howard/Berrang

Identified By: Smith/Schultz/Foster | Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-03M	Sample #:	Sample #:	Bottom:

	Total	% of Sample
DIPTERA	20	30.3%
DIPTERA	15	22.73%
PLECOPTERA	11	16.67%
DIPTERA	4	6.06%
DIPTERA	4	6.06%
OLIGOCHAETA	2	3.03%
DIPTERA	1	1.52%
DIPTERA	1	1.52%
DIPTERA	1	1.52%
DIPTERA	1	1.52%
DECAPODA	1	1.52%
ODONATA	1	1.52%
ODONATA	1	1.52%
EPHEMEROPTERA	1	1.52%
DIPTERA	1	1.52%
TRICHOPTERA	1	1.52%

EQUITABILITY (Diversity due to species composition): 0.69

PERCENT CONTRIBUTION OF DOMINANT TAXON: Parametriocnemus sp. 20 30.3 %

FUNCTIONAL FEEDING GROUPS

unknown	38	57.58%
Shredder	20	30.3%
Predator......... ..	3	4.55%
Collector Gatherer.	3	4.55%
Scraper	1	1.52%
Collector Filterer.	1	1.52%
Piercer	0	00%

Water Body : Laurel Fork
Date Placed :
Date Collected : 5/3/00
Collector : Howard/Weldon
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Bactor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-04R	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	#Mx	REPLIC 2 Count	#Mx	REPLIC 3 Count	#Mx	COMPOSITE Count	#Mx
DTPTERA	*Tipula sP.*	1	1					1	
DIPTERA	*Dicranota sp.*	1	1					1	
DIPTERA	*Hemerodromia sp.*	11	11					11	
DIPTERA	*Parametriocnemus sp.*	23	23					23	
DIPTERA	*Eukiefferiella devonica gp.*	1	1					1	
DIPTERA	*Eukiefferiella claripennis gp.*	9	9.					9	
DIPTERA	*Cricotopus bicinctus*	137	137					137	
DIPTERA	*Orthacladius sp.*	10	10					10	
DIPTERA	*Chaetocladius sp.*	1	1					1	
DIPTERA	*Tanytarsus sp.*	1	1					1	
COLEOPTERA	*Stenelmis sp.*	3	3					3	
PLECOPTERA	*Perlesta sp.*	1	1					1	
PLECOPTERA	*2nd genus (immature)*	1	1					1	
TRICHOPTERA	*Cheumatopsyche sp.*	13	13					13	
TRICHOPTERA	*Hydropsyche sp.*	12	12					12	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
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								0	
MACROINVERTEBRATE	TOTALS:	225	225	0	0	0	0	225	0
BIOLOGY DATA SHEET	# OF TAXA:	15		0		0		15	
	DIVERSITY INDEX:		2.16		0		0		2.16

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Laurel Fork
Date Placed :
Date Collected : 5/3/00
Collector : Howard/Weldon
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-04R	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 3	20%	CLASS I INDIV.	: 150	66.67%
CLASS II SPECIES	: 1	6.67%	CLASS II INDIV.:	13	5.78%
CLASS III SPECIES:	0	0%	CLASS 111 INDIV:	0	0%
CLASS IV SPECIES	: 2	13.33%	CLASS IV INDIV.:	4	1.78%
CLASS V SPECTES	: 9	60%	CLASS V INDIV.	: 58	25.78%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	15	3	1
EPT INDEX	4	3	3
% CONTRIBUTION OF DOMINANT TAXON	60.89 %	1	1
FLORIDA INDEX	7	5	1
% DIPTERA	86.67 %	1	1
% COLLECTOR-FILTERERS	11.56 %	5	5
% SHREDDERS	61.33 %	3	3
% CRUSTACEANS AND MOLLUSKS	0 %	1	---
# CRUSTACEANS AND MOLLUSKS	a	1	---
SCORES		23	15
EVALUATION		Moderate Impairment	Moderate Impairment

COMMUNITY DISTRIBUTION REPORT

Water Body : Laurel Fork
Date Placed :
Date Collected : 5/3/00
Collector : Howard/Weldon
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-04R	Sample #:	Sample #:	Bottom:

	Total	% of Sample
DIPTERA	137	60.89%
DTPTERA	23	10.224
TRICHOPTERA	13	5.78%
TRICHOPTERA	12	5.33%
DIPTERA	11	4.89%
DIPTERA	10	4.44%
DIPTERA	9	4%
COLEOPTERA	3	1.33%
DIPTERA	1	0.44%
DIPTERA	1	0.44%
DIPTERA	1	0.44%
PLECOPTERA	1	0.44%
PLECOPTERA	1	0.44%
DIPTERA	1	0.44%
DIPTERA	1	0.44%

EQUITABILITY (Diversity due to species composition): 0.40

PERCENT CONTRIBUTION OF DOMINANT TAXON: Cricotopus bicinctus 137 60.89 %

FUNCTIONAL FEEDING GROUPS

Shredder...........	138	61.33%
Unknown...	49	21.78%
Collector Filterer.	26	11.56%
Predator...........	12	5.33%
Scraper............	0	00%
Collector Gatherer.	0	00%
Piercer............	0	00%

Water Body : Laurel Fork
Date Placed. :
Date Collected : 5/3/00
Collector : Howard/Weldon
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-04M	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	#M»	REPLIC 2 Count	#M»	REPLIC 3 count	#M»	COMPOSITE Count	#M»
DIPTERA	*Procladius sp.*	2	2					2	
DIPTERA	*Chaetocladius sp.*	1	1					1	
DIPTERA	*Tvetenia bavarica gp.*	3	3					3	
DIPTERA	*Parametriocnemus sp.*	8	8					8	
DIPTERA	*Cricotopus sp.*	10	10					10	
DIPTERA	*Orthocladius sp.*	2	2					2	
DIPTERA	*Phaenopsectra sp.*	1	1					1	
DIPTERA	*Chironomus sp.*	16	16					16	
DIPTERA	*Polypedilum illi/trit*	3	3					3	
DIPTERA	*Tanytarsus sp.*	5	5					5	
ODONATA	*Calopteryx sp.*	1	1					1	
ODONATA	*Gomphidae unid.*	2	2					2	
ODONATA	*Argia sp.*	1	1					1	
COLEOPTERA	*Helichus sp.*	2	2					2	
COLEOPTERA	*Dubiraphia sp.*	1	1					1	
COLEOPTERA	*Stenelmis sp.*	4	4					4	
COLEOPTERA	*Macronychus sp.*	1	1					1	
OLIGOCHAETA	*Limnodrilus sp.*	2	2					2	
PLECOPTERA	*Allocapnia sp.*	1	1					1	
PLECOPTERA	*Amphinemura sp.*	2	2					2	
PLECOPTERA	*Isoperla sp.*	3	3					3	
TRICHOPTERA	*unknown pupa*	1	1					1	
TRICHOPTEFA	*Cheumatopsyche sp.*	9	9					9	
TRICHOPTEFA	*Hydropsyche sp.*	3	3					3	
TRICHOPTERA	*Limnephilidae unid.*	1	1					1	
DIPTERA	*Chironomidae (larvae)*	2	2					2	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
MACROINVERTEBRATE	TOTALS:	87	87	0	0	0	0	87	0
BIOLOGY DATA SHEET	# OF TAXA:	26		0		0		26	
	DIVERSITY INDEX:		4.12		0		0		4.12

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Laurel Fork
Date Placed :
Date Collected : 5/3/00
Collector : Howard/Weldon
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-04M	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	3	11.54%	CLASS I INDIV.	5	5.75%
CLASS II SPECIES	3	11.54%	CLASS II INDIV.	21	24.14%
CLASS III SPECIES	3	11.54%	CLASS III INDIV	20	22.49%
CLASS IV SPECIES	3	11.54%	CLASS IV INDIV.	7	8.05%
CLASS V SPECIES	14	53.85%	CLASS V INDIV.	34	39.08%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	26	3	3
EPT INDEX	7	3	5
% CONTRIBUTION OF DOMINANT TAXON	18.39 %	3	3
FLORIDA INDEX	9	5	3
% DPPTERA	60.92 %	1	1
% COLLECTOR-FILTERERS	19.54 %	5	5
% SHREDDERS	17.24 %	3	3
% CRUSTACEANS AND MOLLUSKS	0 %	1	---
# CRUSTACEANS AND MOLLUSKS	0	1	---
SCORES		25	23
EVALUATION		Moderate Impairment	No Impairment

COMMUNITY DISTRIBUTION REPORT

Water Body : Laurel Fork
Date Placed : Date Collected : 5/3/00
Collector : Howard/Weldon Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-04M	Sample #:	Sample #:	Bottom:

	Total	% of Sample
DIPTERA	16	18.39%
DIPTEFA	10	11.49%
TRICBOPTERA	9	10.34%
DIPTERA	8	9.2%
DIPTERA	5	5.75%
COLEOPTERR	4	4.6%
DIPTERA	3	3.45%
PLECOPTERA	3	3.45%
DTPTERA	3	3.45%
TRICHOPTERA	3	3.45%
ODONATA	2	2.3%
COLEOPTERA	2	2.3%
DIPTERA	2	2.3%
OLIGOCHAETA	2	2.3%
PLECOPTERA	2	2.3%
DIPTERA	2	2.3%
DIPTERA	2	2.3%
ODONATA	1	1.15%
PLECOPTERA	1	1.15%
COLEOPTERA	1	1.15%
ODONATA	1	1.15%
TRICHOPTERA	1	1.15%
DLPTEFA	1	1.15%
DIPTERA	1	1.15%
TRICHOPTERA	1	1.15%

EQUITABILITY (Diversity due to species composition): 0.96

PERCENT CONTRIBUTION OF DOMINANT TAXON: Chironomus sp. 16 18.39 %

FUNCTIONAL FEEDING GROUPS

unknown............	29	33.33%
Collector Gatherer.	20	22.99%
Collector Filterer.	17	19.54%
Shredder...........	15	17.24%
Predator...........	6	6.9%
Scraper............	0	00%
Piercer............	0	00%

water Body : Fugate Fork
Date Placed :
Collector : Howard/Weldon
Identified By: Smith/Schultz/Foster

Date Collected : 5/2/00
Sorted By : Howard/Berrang
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-05R	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	#M»	REPLIC 2 Count	#Ws	REPLIC 3 Count	#M»	COMPOSITE Count	#M»
DIPTERA	Dicranota sp.	1	1					1	
DIPTERA	Limnophila sp.	4	4					4	
DIPTERA	Simulium sp.	2	2					2	
DIPTERA	Hemerodromia sp.	2	2					2	
DIPTERA	Conchapelopia sp.	3	3					3	
DIPTERA	Parametriocnemus sp.	72	72					72	
DIPTEILR	Diamesa sD.	2	2					2	
DIPTERA	Eukiefferiella claripennis gp	1	1					1	
DIPTERA	Eukiefferiella devonica UD.	8	8					8	
UIPTERA	Tvetenia bavarica UD.	25	25					25	
DIPTEILR	Corynoneura sp.	1	1					1	
DIPTERA	Cricotopus bicinctus	9	9					9	
DIPTERA	Cricotopus trifascia	3	3					3	
DIPTERA	Orthocladius 2 SDD.	6	6					6	
DIPTERA	Parakiefferiella sp.	1	1					1	
MEGALOPTERA	Corydalus sp.	6	6					6	
COLEOPTERA	Psephenus sp.	1	1					1	
COLEOPTERA	Stenelmis sD.	7	7					7	
COLEOPTERA	Optioservus sp.	(27	27					27	
ODONATA	~~Argia sp.~~	1	1					I	
ODONATA	Gomphidae unid.	2	2					2	
EPHEMEROPTERA	Isonychia sD.	2	2					2	
PLECOPTERA	Leuctridae/Capniidae (immature)	1	1					I	
PLECOPTERA	~~Amphinemura sp.~~	44	44					40	
PLECOPTERA	~~Isoperla sp.~~	6	6					6	
TRICHOPTERA	~~Cheumatopsyche sD.~~	5	5					5	
TRLCHOPTERA	Ceratopsyche sp.	1	1					1	
TRICHOPTERA	~~Chimarra sp.~~	18	18					18	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
MACROINVERTEBRATE	TOTALS:	261'	261	0	0	0	0	261	0
BIOLOGY DATA SHEET	# OF TAXA:	28		0		0		28	
	DIVERSITY INDEX:		3.58		0		0		3.58

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Fugate Fork
Date Placed :
Date Collected : 5/2/00
Collector : Howard/Weldon
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-05R	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 5	17.86%	CLASS I INDIV.	: 31	11.88%
CLASS II SPECIES	: 1	3.57%	CLASS II INDIV.:	5	1.92%
CLASS 111 SPECIES:	3	10.71%	CLASS III INDIV:	72	27.59%
CLASS IV SPECIES	: 2	7.11%	CLASS IV INDIV.:	9	3.454
CLASS V SPECIES	: 17	60.71%	CLASS V INDIV.	: 144	55.17%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	28	5	3
EPT INDEX	7	3	5
% CONTRIBUTION Of DOMINANT TAXON	27.59 %	3	1
FLORIDA INDEX	11	5	3
% DIPTERA	53.64 %	1	1
% COLLECTOR-FILTERERS	9.58 %	5	3
% SHREDDERS	20.31 %	3	3
% CRUSTACEANS AND MOLLUSKS	0 %	1	---
# CRUSTACEANS AND MOLLUSKS	0	1	---
SCORES		27	19
EVALUATION		No Impairment	Moderate Impairment

f'

COMMUNITY DISTRIBUTION REPORT

Water Body : Fugate Fork
Date Placed :
Date Collected : 5/2/00
Collector : Howard/Weldon
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth .:	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-05R	Sample #:	Sample #:	Bottom:

	Total	% of Sample
DIPTERA	72	27.59%
PLECOPTERA	44	16.86%
COLEOPTERA	27	10.34%
DIPTERA	25	9.58%
TRICHOPTERA	18	6.9%
DIPTERA	9	3.45%
DIPTERA	8	3.07%
COLEOPTERA	7	2.68%
DIPTERA	6	2.3%
MEGALOPTERA	6	2.3%
PLECOPTERA	6	2.3%
TRICHOPTERA	5	1.92%
DIPTERA	4	1.53%
DIPTERA	3	1.15%
DIPTERA	3	1.15%
DIPTERA	2	0.77%
DIPTERA	2	0.77%
ODONATA	2	0.77%
EPHEMEROPTERA	2	0.77%
DIPTERA	2	0.77%
DIPTERA	1	0.38%
COLEOPTERA	1	0.38%
PLECOPTERA	1	0.38%
ODONATA	1	0.38%
DIPTERA	1	0.38%

EQUITABILITY (Diversity due to species composition): 0.61

PERCENT CONTRIBUTION OF DOMINANT TAXON: Parametriocnemus sp. 72 27.59 %

FUNCTIONAL FEEDING GROUPS

Unknown............	144	55.17%
Shredder...........	53	20.31%
Collector Gatherer.	31	11.88%
Collector Filterer.	25	9.58%
Predator...........	8	3.07%
Scraper............	0	00%
Piercer............	0	00%

Water Body : Fugate Fork
Date Placed : | Date Collected : 5/2/00
Collector : Howard/Weldon | Sorted By : Howard/Borrang
Identified By: Smith/Schultz/Foster | Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Gsabs : I	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-05M	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	REPLIC 1 #M²	REPLIC 2 Count	REPLIC 2 #M²	REPLIC 3 Count	REPLIC 3 #M²	COMPOSITE Count	COMPOSITE #M²
DIPTERA	Tipula sp.	2	2					2	
DIPTERA	Simulium sp.	3	3					3	
DIPTERA	Hemerodromia sp.	1	1					1	
DIPTERA	Clinocera sp.	2	2					2	
DIPTERA	Conchapelopia sp.	2	2					2	
DIPTERA	Parametriocnemus sp.	17	17					17	
DIPTERA	Eukiefferiella claripennis gp.	1	1					1	
DIPTERA	Eukiefferiella devonica gp.	5	5					5	
DIPTERA	Tvetenia bavarica gp.	15	15					15	
DIPTERA	Cricotopus bicinctus	3	3					3	
DIPTERA	Orthocladius sp.	1	1					1	
DIPTERA	Rheocricotopus sp.	1	1					1	
DIPTERA	Tanytarsus sp.	1	1					1	
AMPHIPODA	Astacidae sp.	2	2					2	
COLEOPTERA	Helichus sp.	1	1					1	
COLEOPTERA	Macronychus sp.	2	2					2	
COLEOPTERA	Dubiraphia sp.	3	3					3	
COLEOPTERA	Stenelmis sp.	9	9					9	
COLEOPTERA	Optioservus sp.	3	3					3	
ODONATA	Boveria sp.	1	1					1	
ODONATA	Calopteryx sp.	3	3					3	
OLIGOCHAETA	Lumbriculidae wid.	1	1					1	
OLIGOCHAETA	Tubificidae unid.	1	1					1	
EPHEMEROPTERA	Caenis sp.	2	2					2	
PLECOPTERA	Amphinemura sp.	93	93					93	
PLECOPTERA	Isoperla sp.	27	27					27	
PLECOPTERA	Diploperla sp.	1	1					1	
PEECOPTERA	~~unknown (very immature)~~	2	2					2	
TRICHOPTERA	Cheumatopsyche sp.	1	1					1	
TRICHOPTERA	Hydropsyche sp.	1	1					1	
TRICHOPTERA	~~Ceratopsyche sp. (Hydropsyche sp.)~~	1	1					1	
TRICHOPTERA	~~Chimarra sp.~~	1	1					1	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
MACROINVERTEBRATE	TOTALS:	209	209	0	0	0	0	209	0
BIOLOGY DATA SHEET	# OF TAXA:	32		0		0		32	
	DIVERSITY INDEX:		3.2		0		0		3.2

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Fugate Fork
Date Placed :
Date Collected : 5/2/00
Collector : Howard/Weldon
sorted. By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
sample #: KYM-05M	Sample #:	Sample #:	Bottom:

CLASS I SPECIES :	6	18.75%	CLASS I INDIV. :	12	5.74%
CLASS II SPECIES :	1	3.13%	CLASS II INDIV.:	1	.48%
CLASS III SPECIES:	6	18.75%	CLASS III INDIV:	102	48.3%
CLASS IV SPECIES :	4	12.5%	CLASS IV INDIV.:	15	7.18%
CLASS V SPECIES :	15	46.88%	CLASS V INDIV. :	79	37.8%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	32	5	5
EPT INDEX	9	3	5
% CONTRIBUTION OF DOMINANT TAXON	44.5 %	1	1
FLORIDA INDEX	13	5	3
% DIPTERA	25.84 %	3	3
% COLLECTOR-FZLTERERS	3.35 %	1	1
% SHREDDERS	46.89 %	3	3
% CRUSTACEANS AND MOLLUSKS	.96 %	1	---
# CRUSTACEANS AND MOLLUSKS	1	1	---
SCORES		23	21
EVALUATION		Moderate Impairment	Moderate Impairment

3

Water Body : Simms Fork
Date Placed : Date Collected :
Collector : Howard/Weldon Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grab8 :	Grabs :	Grabs : 1
Sample #: KYM-06R	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	REPLIC 1 #M»	REPLIC 2 Count	REPLIC 2 #M»	REPLIC 3 Count	REPLIC 3 #M»	COMPOSITE Count	COMPOSITE #M»
DIPTERA	Limnophila sp.	13	13					13	
DIPTEFA	Conchapelopia sp.	2	2					2	
DIPTERR	Helopelopia sp.	8	8					8	
DIPTERA	Diamesa sp.	1	1					1	
DIPTERA	Thienemanniella sp.	1	1					1	
DIPTEFA	Parametriocnemus sp.	12	12					12	
DIPTERA	Parakiefferiella sp.	1	1					1	
DIPTERA	Tvetenia sp.	2	2					2	
DIPTERA	Cricotopus tremulus	18	18					18	
DIPTERA	Orthocladius sp.	46	46					46	
DIPTERA	Polypedilum convictum	1	1					1	
DIPTERA	Tanytarsus sp.	1	1					1	
DIPTERR	Rheotanytarsus sp.	1	1					1	
EPHEMEROPTERA	Baetidae (2 tails)	11	11					11	
EPHEMEROPTERA	Ephemerella sp.	15	5					5	
EPHEMEROPTERA	Eurylophella sp.	1	1					1	
EPHEMEROPTERA	Drunella sp.	5	5					5	
EPHEMEROPTERA	Epeorus sp.	6	6					6	
EPHEMEROPTERA	Cinygmula sp.	10	10					10	
EPHEMEROPTERA	Stenonema sp.	1	1					1	
EPHEMEROPTERA	Caenis sp.	7	7					7	
EPHEMEROPTEFA	Habrophlebiodes/Paraleptophlebia imm	1	1					1	
PLECOPTERA	Allocapnia sp.	4	4					4	
PLECOPTERA	Amphinemura sp.	11	11					11	
PLECOPTERA	Isoperla sp.	1	1					1	
TRIMOPTERA	Cheumatopsyche sp.	3	3					3	
TRICHOPTERA	Ceratopsyche SD. (Hydropsyche sp.)	1	1					1	
TRICHOPTERA	Diplectrona sp.	1	1					1	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
MACROINVERTEBRATE	TOTALS:	175	175	0	0	0	0	175	0
BIOLOGY DATA SHEET	# OF TAXA:	28		0		0		28	
	DIVERSITY INDEX:		3.86		0		0		3.86

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Simms Fork
Date Placed :
Date Collected :
Collector : Howard/Weldon
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-06R	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 3	10.71%	CLASS I INDIV.	: 9	5.14%
CLASS II SPECTES	: 2	7.14%	CLASS'TI INDIV.:	8	4.5'7%
CLASS III SPECIES:	2	7.14%	CLASS 111 INDIV:	18	10.29%
CLASS IV SPECIES	: 1	3.57%	CLASS IV INDIV.:	1	.57%
CLASS V SPECIES	: 20	71.43%	CLASS V INDIV.	: 139	79.43%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	28	5	3
EPT INDEX	15	3	5
% CONTRIBUTION OF DOMINANT TAXON	26.29 %	3	1
FLORIDA INDEX	8	5	1
% DIPTERA	61.14 %	1	1
% COLLECTOR-FILTERERS	2.86 %	3	1
% SHREDDERS	6.29 %	1	1
% CRUSTACEANS AND MOLLUSKS	0 %	1	---
# CRUSTACEANS AND MOLLUSKS	0	1	---
SCORES		21	13
EVALUATION		Moderate Impairment	Severe Degradation

COMMUNITY DISTRIBUTION REPORT
3

Water Body : Simms Fork
Date Placed : | Date Collected :
Collector : Howard/Weldon | Sorted By : Howard/Barrang
Identified By: Smith/Schultz/Foster | Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-06R	Sample #:	Sample #:	Bottom:

	Total	% of Sample
DIPTERA	46	26.29%
DIPTERA	18	10.29%
DIPTERA	13	7.43%
DIPTERA	12	6.86%
EPHEMEROPTERA	11	6.29%
PLECOPTEM	11	6.29%
EPHEMEROPTERA	10	5.71%
DIPTERA	8	4.57%
EPHEMEROPTERA	7	4%
EPHEMEROPTERA	6	3.43%
EPHEMEROPTERA	5	2.86%
EPHEMEROPTERA	5	2.86%
PLECOPTERA	4	2.29%
TRICHOPTERA	3	1.71%
DIPTERA	2	1.14%
DIPTERA	2	1.14%
DIPTERA	1	0.57%
DIPTEM	1	0.57%
DIPTERA	1	0.57%
EPHEMEROPTERA	1	0.57%
EPHEMEROPTERA	1	0.57%
EPHEMEROPTERA	1	0.57%
DIPTERA	1	0.57%
DIPTERA	1	0.57%
PLECOPTERA	1	0.57%

EQUITABILITY (Diversity due to species composition): 0.79

PERCENT CONTRIBUTION OF DOMINANT TAXON: Orthocladius sp. 46 26.29 %

FUNCTIONAL FEEDING GROUPS

Unknown............	136	77.71%
Collector Gatherer.	20	11.43%
Shredder...........	11	6.29%
Collector Filterer.	5	2.86%
Predator...........	2	1.14%
Scraper............	1	0.57%
Piercer............	0	00%

Water Body : Spring Fk Quicksand Cr
Date Placed : Date Collected : 5/2/00
Collector : Howard/Weldon .Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-07R	Sample #:	Sample #:	Bottom:

	ORGANISMS	REPLIC 1 Count	#M»	REPLIC 2 Count	#M»	REPLIC 3 Count	#M»	COMPOSITE Count	#M»
DIPTERA	Limnophila sp.	6	6					6	
DIPTERA	Simulium sp.	1	1					1	
DIPTERA	Hemerodromia sp.	7	7					7	
DIPTERA	Conchapelopia sp.	4	4					4	
DIPTERA	Zavrelimyia sp.	1	1					1	
DIPTERA	Parametriocnemus sp.	25	25					25	
DIPTERA	Cricotopus tremulus	10	10					10	
DIPTERA	Orthocladius sp.	101	101					101	
DIPTERA	Tvetenia bavarica gp.	3	3					3	
DIPTERA	Parakiefferiella sp.	1	1					1	
DIPTERA	Eukiefferiella claripennis	3	3					3	
DIPTERA	Polypedilum scalaenum	1	1					1	
DECAPODA	Astacidae unid.	2	2					2	
ODONATA	Calopteryx sp.	2	2					2	
ODONATA	Stylogomphus sp.	1	1					1	
ODONATA	Cordulegaster sp.	1	1					1	
OLIGOCHAETA	Limnodrilus sp.	2	2					2	
OLIGOCHAETA	Tubificidae unid.	5	5					5	
EPHEMEROPTERA	Baetidae (2 tails)	3	3					3	
EPHEMEROPTERA	Ephemerella sp.	1	1					1	
EPHEMEROPTERA	Stenacron sp.	1	1					1	
PLECOPTERA	Amphinemura sp.	2	2					2	
PLECOPTERA	Isoperla sp.	2	2					2	
TRICEOPTERA	Rhyacophila sp.	1	1					1	
DIPTERA	Chironomidae (pupa)	1	1					1	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
MACROINVERTEBRATE	TOTALS:	187	187	0	0	0	0	187	0
BIOLOGY DATA SHEET	# OF TAXA:	25		0		0		25	
	DIVERSITY INDEX:		2.73		0		0		2.73

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Spring Fk Quicksand Cr
Date Placed : Date Collected : 5/2/00
Collector : Howard/Weldon Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster ..Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-07R	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 2	8%	CLASS I INDIV.	: 3	1.6%
CLASS II SPECIES	: 2	8%	CLASS II INDIV.:	2	1.07%
CLASS I11 SPECIES:	4	16%	CLASS III INDIV:	10	5.35%
CLASS IV SPECIES	: 0	0%	CLASS IV INDIV.:	0	0%
CLASS V SPECIES	: 17	68%	CLASS V INDIV. :	172	91.98%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	25	3	3
EPT INDEX	6	3	3
% CONTRIBUTION OF DOMINANT TAXON	54.01 %	1	1
FLORIDA INDEX	6	3	1
% DIPTERA	87.7 %	1	1
% COLLECTOR-FILTERERS	.53 %	1	1
% SHREDDERS	1.6 %	1	1
% CRUSTACEANS AND MOLLUSKS	1.07 %	1	---
# CRUSTACEANS AND MOLLUSKS	1	1	---
SCORES		15	11
EVALUATION		Severe Degradation	Severe Degradation

COMMUNITY DISTRIBUTION REPORT

Water Body : Spring Fk Quicksand Cr
Date Placed : Date collected : 5/2/00
Collector : Howard/Weldon Sorted By : Howard/Barrang
Identified By: Smith/Schultz/Foster Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-07R	Sample #:	Sample #:	Bottom:

	Total	% of Sample
DIPTERA	101	54.01%
DIPTERA	25	13.37%
DIPTERA	10	5.35%
DIPTERA	7	3.74%
DIPTERA	6	3.21%
OLIGOCHAETA	5	2.67%
DIPTERA	4	2.14%
DIPTERA	3	1.6%
DIPTERA	3	1.6%
EPHEMEROPTERA	3	1.6%
DECAPODA	2	1.07%
ODONATA	2	1.07%
OLIGOCHAETA	2	1.07%
PLECOPTEM	2	1.07%
PLECOPTERA	2	1.07%
ODONATA	1	0.53%
DIPTERA	1	0.53%
DIPTERA	1	0.53%
DIPTERA	1	0.53%
EPHEMEROPTERA	1	0.53%
EPHEXEROPTERA	1	0.53%
DIPTERA	1	0.53%
OJJONATA	1	0.53%
TRICHOPTERA	1	0.53%
DIPTERA	1	0.53%

EQUITABILITY (Diversity *due* to species composition): 0.36

PERCENT CONTRIBUTION OF DOMINANT TAXON: Orthocladius sp. 101 54.01 %

FUNCTIONAL FEEDING GROUPS

Unknown............	157	83.96%
Predator...........	16	8.56%
Collector Gatherer.	9	4.81%
Shredder...........	3	1.6%
Scraper............	1	0.53%
Collector Filterer.	1	0.53%
Piercer............	0	00%

Water Body : Spring FR Quicksand Cr
Date Placed : | Date Collected : 5/2/00
Collector : Howard/Weldon | Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster | Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-07M	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	REPLIC 1 #M²	REPLIC 2 Count	REPLIC 2 #M²	REPLIC 3 Count	REPLIC 3 #M²	COMPOSITE Count	COMPOSITE #M²
DIPTERA	*Bezzia sp.*	1	1					1	
DIPTERA	*Conchapelopia sp.*	1	1					1	
DIPTERA	~~*Helopelopia sp.*~~	2	2					2	
DIPTERA	*Parametriocnemus sp.*	1	1					1	
DIPTERA	*Parakiefferiella sp.*	1	1					1	
DIPTERA	*Cricotopus bicinctus*	1	1					1	
DIPTERA	*Orthocladius sp.*	7	7					7	
DIPTERA	*Thienemanniella xena type*	1	1					1	
DIPTERA	*Polypedilum tritum type*	3	3					3	
OLIGOCHAETA	*Tubificidae unid.*	16	16					16	
OPONATA	*Gomphidae unid.*	1	1					1	
MEGALOPTERA	*Sialis sp.*	1	1					1	
COLEOPTERA	*Stenelmis sp.*	1	1					1	
COLEOPTEU	*Optioservus sp.*	2	2					2	
EPHEMEROPTERA	*Baetidae (3 tails,immature)*	1	1					1	
EPHEMEROPTERA	*Eurylophella sp.*	1	1					1	
EPHEMEROPTERA	*Caenis sp.*	1	1					1	
PLECOPTERA	*Amphinemura sp.*	9	9					9	
PLECOPTERA	*Isoperla sp.*	1	1					1	
								0	
								0	
								0	
								0	
								0	
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								0	
MACROINVERTEBRATE	TOTALS:	52	52	0	0	0	0	52	0
BIOLOGY DATA SHEET	# OF TAXA:	19		0		0		19	
	DIVERSITY INDEX:		3.37		0		0		3.37

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Spring Pk Quicksand Cr
Date Placed :
Date Collected : 5/2/00
Collector : Howard/Weldon
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-07M	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 2	10.53%	CLASS I INDIV.	: 2	3.85%
CLASS II SPECIES	: 0	0%	CLASS II INDIV.:	0	0%
CLASS III SPECIES:	4	21.05%	CLASS III INDIV:	28	53.85%
CLASS IV SPECIES	: 1	5.26%	CLASS IV INDIV.:	1	1.92%
CLASS V SPECIES	: 12	63.16%	CLASS V INDIV.	: 21	40.38%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	19	3	3
EPT INDEX	5	3	3
% CONTRIBUTION OF DOMINANT TAXON	30.77 %	3	1
FLORIDA INDEX	4	3	1
% DIPTERA	34.62 %	1	3
% COLLECTOR-FLLTERERS	0 %	1	1
% SHREDDERS	25 %	3	3
% CRUSTACEANS AND MOLLUSKS	0 %	1	---
# CRUSTACEANS AND MOLLUSKS	0	1	---
SCORES		19	15
EVALUATION		Moderate Impairment	Moderate Impairment

COMMUNITY DISTRIBUTION REPORT

Water Body : Spring Fk Quicksand Cr
Date Placed : Date Collected : 5/2/00
Collector : Howard/Weldon Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster Sample Mechanism:

REPLICXTE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-07M	Sample #:	Sample #:	Bottom:

	Total	% of Sample
OLIGOCHAETA	16	30.77%
PLECOPTERA	9	17.31%
DIPTERA	7	13.46%
DIPTERA	3	5.77%
DIPTERA	2	3.85%
COLEOPTERA	2	3.85%
DIPTERA	1	1.92%
DIPTERA	1	1.92%
DIPTERA	1	1.92%
DIPTERA	1	I.92%
ODONATA	1	1.92%
MEGALOPTERA	1	1.92%
COLEOPTERA	1	1.92%
DIPTERA	1	1.92%
EPHEMEROPTERA	1	1.92%
EPHEMEROPTERA	1	I.92%
EPHEMEROPTERA	1	I.92%
DIPTERA	1	1.92%
PLECOPTERA	1	1.92%

EQUITABILITY (Diversity due to species composition): 0.79

PERCENT CONTRIBUTION OF DOMINANT TAXON: Tubificidae unid. 16 30.77 %

FUNCTIONAL FEEDING GROUPS

Collector Gatherer.	20	38.46%
Unknown............	15	28.85%
Shredder......	13	25%
Predator.......	3	5.77%
scraper............	I	1.92%
Collector Filterer.	0	00%
Piercer............	0	00%

Water Body : Lost Creek
Date Placed : 3
Date Collected : 5/2/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-09R	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	REPLIC 1 #M»	REPLIC 2 Count	REPLIC 2 #M»	REPLIC 3 Count	REPLIC 3 #Ma	COMPOSITE Count	COMPOSITE #M»
DIPTERA	*Simulium sp.*	1	1					1	
DIPTERA	*Ceratopogon sp.*	1	1					1	
DIPTERA	*Bezzia sp. (2 spp.)*	2	2					2	
DIPTERA	*Hemerodromia* sp.	2	2					2	
DIPTERA	*Krenopelopia sp.*	1	1					1	
DIPTERA	*Parametriocnemus sp.*	58	58					58	
DIPTERA	*Cricotopus sp.*	35	35					35	
DIPTERA	*Tanytarsus sp.*	2	2					2	
AMPHIPODA	*Astacidae unid.*	1	1					1	
OLIGOCHAETA	*Lumbriculidae unid.*	2	2					2	
COLEOPTERA	*Optioservus sp.*	3	3					3	
MEGALOPTERA	*Sialis sp.*	1	1					1	
ODONATA	*Progomphus sp.*	1	1					1	
ODONATA	*Stylogomphus sp.*	1	1					1	
OLIGOCHAETA	*Limnodrilus sp.*	3	3					3	
TRICHOPTERA	*Cheumatopsyche sp.*	4	4					4	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
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								0	
								0	
								0	
MACROINVERTEBRATE BIOLOGY DATA SHEET	TOTALS:	118	118	0	0	0	0	118	0
	# OF TAXA:	16		0		a		16	
	DIVERSITY INDEX:		2.27		0		0		2.27

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Lost Creek
Date Placed :
Date Collected : 5/2/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-09R	sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 2	12.5%	CLASS I INDIV.	: 2	1.69%
CLASS II SPECIES	: 2	12.5%	CLASS II INDIV.	: 39	33.05%
CLASS III SPECIES	: 3	18.75%	CLASS III INDIV	: 8	6.78%
CLASS IV SPECIES	: 0	0%	CLASS IV INDIV.	: 0	0%
CLASS V SPECIES	: 9	56.25%	CLASS V INDIV.	: 69	58.47%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	16	3	3
EPT INDEX	1	1	1
% CONTRIBUTION OF DOMINANT TAXON	49.15 %	1	1
FLORIDA INDEX	6	3	1
% DIPTERA	86.44 %	1	1
% COLLECTOR-FILTERERS	5.93 %	3	1
% SHREDDERS	29.66 %	3	3
% CRUSTACEANS AND MOLLUSKS	.a5 %	1	---
# CRUSTACEANS AND MOLLUSKS	1	1	---
SCORES		17	11
EVALUATION		Moderate Impairment	Severe Degradation

COMMUNITY DPSTRIBUTION REPORT

Water Body : Lost Creek
Date Placed :
Date Collected : 5/2/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-09R	Sample #:	Sample #:	Bottom:

	Total	% of Sample
DIPTERA	58	49.15%
DIPTERA	35	29.66%
TRICHOPTERA	4	3.39%
COLEOPTERA	3	2.54%
OLIGOCHAETA	3	2.54%
DIPTERA	2	1.69%
OLIGOCHAETA	2	1.69%
DIPTERA	2	1.69%
DIPTERA	2	1.69%
DIPTEFA	1	0.85%
DIPTERA	1	0.85%
MEGALOPTERA	1	0.85%
ODONATA	1	0.85%
ODONATA	1	0.85%
DIPTERA	1	0.85%
AMPHIPODA	1	a.85%

EQUITABILITY (Diversity due to species composition): 0.38

PERCENT CONTRIBUTION OF DOMINANT TAXON: Parametriocnemus sp. 58 49.15 %

FUNCTIONAL FEEDING GROUPS

Unknown............	64	54.24%
Shredder...........	35	29.66%
Collector Gatherer.	8	6.78%
Collector Filterer.	7	5.93%
Predator...........	4	3.39%
Scraper............	0	00%
Piercer...........	0	00%

Water Body : Lost Creek
Date Placed :
Dare Collected : 5/2/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Barrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 3	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-09M	Sample #:	Sample #:	BoEtom:

ORGANISPIS		REPLIC 1 Count	#M»	REPLIC 2 Count	#M»	REPLIC 3 Count	#M»	COMPOSITE count	#M»
DIPTERA	*Tipula sp.*	1	1					1	
DIPTERA	*Ormosia sp.*	1	1					1	
DIPTERR	*Hemerodromia sp.*	1	1					1	
DIPTERA	*Conchapelopia sp.*	1	1					1	
DIPTERA	~~*Parametriocnemus sp.*~~	23	23					23	
DTPTERA	*Cricotopus* bicinctus	11	11					11	
DIPTERA	~~*Orthocladius sp.*~~	1	1					1	
DIPTERA	~~Tvetenia sp.~~	1	1					1	
OLIGOCHAETA	*Lumbriculidae* unid.	3	3					3	
ODONATA	~~*Calopteryx sp.*~~	7	7					7	
MEGALOPTERA	~~*Nigronia sp.*~~	1	1					1	
COLEOPTERA	~~*Dubiraphia sp.*~~	1	1					1	
COLEOPTERA	~~*Microcylloepus sp.*~~	1	1					1	
COLEOPTERA	*Psephenus sp.*	1	1					1	
OLIGOCHAETA	*Tubificidae unid.*	1	1					1	
EPHEMEROPTERA	~~*Baetidae* (2 tails)~~	1	1					1	
EPHEMEROPTERA	~~*Ephemerella sp.*~~	3	3					3	
PLECOPTERR	~~*Isoperla sp.*~~	1	1					1	
TRICHOPTERA	~~*Cheumatopsyche sp.*~~	8	8					8	
DIPTERA	~~Chironomidae (larva)~~	1	1					1	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
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								0	
								0	
MACROINVERTEBRATE	TOTALS:	69	69	0	0	0	0	69	0
BIOLOGY DATA SHEET	# OF TAXA:	20		0		0		20	
	DIVERSITY INDEX:		3.28		0		0		3.28

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Lost Creek
Date Placed :
Date Collected : 5/2/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-09M	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 3	15%	CLASS I INDIV.	: 19	27.54%
CLASS II SPECIES	: 2	10%	CLASS II INDIV.:	11	15.94%
CLASS III SPECTES:	3	15%	CLASS III INDIV:	5	7.25%
CLASS IV SPECIES	: 3	15%	CLASS IV INDIV.:	3	4.35%
CLASS V SPECIES	: 9	45%	CLASS V INDIV.	: 31	44.93%

INVERTEBRATE BIOLOGICAL INDEX *for* STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	20	3	3
EPT INDEX	*4*	3	3
% CONTRIBUTION OF DOMINANT TAXON	33.33 %	3	1
FLORIDA INDEX	8	5	1
% DIPTERA	59.42 %	1	1
% COLLECTOR-FILTERERS	11.59 %	5	5
% SHREDDERS	17.39 %	3	3
% CRUSTACEANS AND MOLLUSKS	*0 %*	1	---
# CRWSTACEANS AND MOLLUSKS	*0*	1	---
SCORES		25	17
EVALUATION		Moderate Impairment	Moderate Impairment

COMMUNITY DISTRIBUTION REPORT

Water Body : Lost Creek

Date Placed :
Data Collected : 5/2/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-09M	Sample #:	Sample #:	Bottom:

	Total	% of Sample
DIPTERA	23	33.33%
DIPTERA	11	15.94%
TRICHOPTERA	8	11.59%
ODONATA	7	10.14%
OLIGOCHAETA	3	4.35%
EPHEMEROPTERA	3	4.35%
DIPTERA	1	1.45%
DIPTERA	1	1.45%
DIPTERA	1	1.45%
DIPTERA	1	1.45%
MEGALOPTERA	1	1.45%
COLEOPTERA	1	1.45%
COLEOPTERA	1	1.45%
COLEOPTERA	1	1.45%
OLIGOCEAETA	1	1.45%
EPHEMEROPTERA	1	1.45%
DIPTERA	1	1.45%
PLECOPTERA	1	1.45%
DIPTERA	1	1.45%
DIPTERA	1	1.45%

EQUITABILITY (Diversity due to species composition): 0.70

PERCENT CONTRIBUTION OF DOMINANT TAXON: Parametriocnemus sp. 23 33.33 %

FUNCTIONAL FEEDING GROUPS

Unknown............	29	42.03%
Shredder...........	12	17.39%
Predator...........	10	14.49%
collector Gatherer.	10	14.49%
Collector Filterer.	8	12.59%
scraper............	0	00%
Piercer...........	0	00%

Water Body : Clemons Fork
Date Placed :
Collector : Howard/Weldon
Identified By: Smith/Schultz/Foster
Date Collected : 5/2/00
Sorted By : Howard/Berrang
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-10R	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	#Mn	REPLIC 2 Count	#M»	REPLIC 3 Count	#M»	COMPOSITE Count	#M»
DIPTERA	Tipula sp.	3	3					3	
DIPTERA	Pseudolimnophila sp.	14	14					14	
DIPTERA	Hexatoma sp.	2	2					2	
DIPTERA	Simulium sp.	13	13					13	
DIPTERA	Prosimulium sp.	7	7					7	
DIPTERA	Helopelopia sp.	5	5					5	
DIPTERA	Parametriocnemus sp.	1	1					1	
DIPTERA	Eukiefferiella claripennis gp.	3	3					3	
DIPTERA	Demicryptochironomus sp.	1	1					1	
DIPTERA	Tanytarsus sp.	1	1					1	
COLEOPTERA	Anchytarsus sp.	1	1					1	
COLEOPTERA	Psephenus sp.	2	2					2	
COLEOPTERA	Helichus sp.	1	1					1	
COLEOPTERA	Stenelmis sp.	2	2					2	
COLEOPTERA	Ectopria sp.	1	1					1	
COLEOPTERA	Optioservus sp.	2	2					2	
ODONATA	Stylogomphus sp.	4	4					4	
EPHEMEROPTERA	Baetidae 12 tails)	34	34					34	
EPHEMEROPTERA	Drunella sp.	16	16					16	
EPHEMEROPTERA	Ephemerella sp.	81	81					81	
EPHEMEROPTERA	Eurylophella sp.	2	2					2	
EPHEMEROPTERA	Stenonema sp.	2	2					2	
EPHEMEROPTERA	Cinygmula sp.	4	4					4	
EPHEMEROPTERA	Epeorus sp.	6	6					6	
EPHEMEROPTERA	Stenacron sp.	2	2					2	
EPHEMEROPTERA	Habrophlebiodes/Paraleptophlebia	1	1					1	
PLECOPTERA	Leuctridae/Capniidae (immature)	1	1					1	
PLECOPTERA	Amphinemura sp.	30	30					30	
PLECOPTERA	Isoperla sp.	7	7					7	
TRICHOPTERA	Helicopsyche sp.	1	1					1	
TRICHOPTERA	Polycentropus sp.	1	1					1	
TRICHOPTERA	Rhyacophila sp.	2	2					2	
TRICHOPTERA	Lepidostoma sp.	1	1					1	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
MACROINVERTEBRATE	TOTALS:	254	254	a	0	0	0	254	0
BIOLOGY DATA SHEET	# OF TAXA:	33		0		0		33	
	DIVERSITY INDEX:		3.63		0		0		3.63

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Clemons Fork
Date Placed :
Date Collected : 5/2/00
Collector : Howard/Weldon
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-10R	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 4	12.12%	CLASS I INDIV.	: 21	8.27%
CLASS II SPECIES	: 2	6.06%	CLASS II INDIV.:	83	32.68%
CLASS III SPECIES:	3	9.09%	CLASS III INDIV:	34	13.39%
CLASS IV SPECIES	: 5	15.15%	CLASS IV INDLV.:	8	3.15%
CUSS V SPECIES	: 19	57.58%	CLASS V INDIV.	: 108	42.52%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	33	5	5
EPT INDEX	16	3	5
% CONTRIBUTION OF DOMINANT TAXON	31.89 %	3	1
FLORIDA INDEX	10	5	3
% DIPTERA	19.69 %	3	3
% COLLECTOR-FILTERERS	5.51 %	3	1
% SHREDDERS	13.39 %	3	3
% CRUSTACEANS AND MOLLUSKS	0 %	1	---
# CRUSTACEANS AND MOLLUSKS	0	1	---
SCORES		27	21
EVALUATION		No Impairment	Moderate Impairment

Water Body : Clemons Fork
Date Placed :
collector : Howard/Weldon
Identified By: Smith/Schultz/Foster

Date Collected : 5/2/00
Sorted By : Howard/Berrang
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-10M	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	#M»	REPLIC 2 Count	#M»	REPLIC 3 Count	#M»	COMPOSITE Count	#M»
DIPTERA	*Tipula sp.*	6	6					6	
DIPTERA	*Simulium sp.*	3	3					3	
DIPTERA	*Helopelopia sp.*	1	1					1	
DIPTERA	*Parametriocnemus sp.*	1	1					1	
DIPTERA	*Oxthocladiua (E.) type II*	1	1					1	
DIPTERA	*Orthocladius obumbratus*	4	4					4	
DIPTERA	*Chironomus sp.*	1	1					1	
DIPTERA	*Polypedilum aviceps*	2	2					2	
DIPTERA	*Tanytarsus sp.*	1	1					1	
DECAPODA	*Astacidae unid.*	1	1					1	
OLIGOCKAETA	*Lumbriculidae unid.*	1	1					1	
COLEOPTERR	*Anchytarsus sp.*	1	1					1	
COLEOPTERA	*Helichus sp.*	6	6					6	
COLEOPTERA	*Berosus sp.*	1	1					1	
EPHEMEROPTERA	*Baetidae (2 tails)*	11	11					11	
EPHEMEROPTERA	*Baetidae (3 tailed/hind wins pad)*	2	2					2	
EPHEMEROPTERA	*Ephemerella sp.*	114	114					114	
EPHEMEROPTERA	*Eurylophella sp.*	21	21					21	
EPHEMEROPTERA	*Habrophlebia sp.*	1	1					1	
EPHEMEROPTERA	*Ameletus sp.*	1	1					1	
PLECOPTERA	*Amphinemura sp.*	51	51					51	
PLECOPTERA	*Isoperla sp.*	10	10					10	
PLECOPTERA	*Remenus sp.*	3	3					3	
TRICHOPTERA	*Pycnopsyche sp.*	2	2					2	
TRICHOPTERA	*Rhyacophila sp.*	1	1					1	
DIPTERA	*Simuliidae unid.(larva)*	1	1					1	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
MACROINVERTEBRATE BIOLOGY DATA SHEET	TOTALS:	248	248	0	0	0	0	248	0
	# OR TAXA:	26		0		0		26	
	DIVERSITY INDEX:		2.77		0		0		2.77

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Clemons Fork
Date Placed : | Date Collected : 5/2/00
Collector : Howard/Weldon | Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster | Sample mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-10M	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 1	3.85%	CLASS I INDIV.	: 3	1.21%
CLASS II SPECIES	: 1	3.85%	CLASS 11 INDIV.	: 114	45.97%
CLASS III SPECIES	: 3	11.54%	CLASS III INDIV	: 53	21.37%
CLASS IV SPECIES	: 4	15.38%	CLASS IV INDIV.	: 14	5.65%
CLASS V SPECIES	: 17	65.38%	CLASS V INDIV.	: 64	25.81%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	26	3	3
EPT INDEX	11	3	5
% CONTRIBUTION OF DOMINANT TAXON	45.97 %	1	1
FLORIDA INDEX	3	1	1
% DIPTERA	8.47 %	3	3
% COLLECTOR-FILTERERS	1.61 %	1	1
4 SHREDDERS	22.98 %	3	3
% CRUSTACEANS AND MOLLUSKS	.4 %	1	---
# CRUSTACEANS AND MOLLUSKS	1	1	---
SCORES		17	17
EVALUATION		Moderate Impairment	Moderate Impairment

COMMUNITY DISTRIBUTION REPORT

water Body : Clemons Pork
Date Placed :
Date Collected : 5/2/00
Collector : Howard/Weldon
sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-10M	Sample #:	Sample #:	Bottom:

	Total	% of Sample
EPHEMEROPTERA	114	45.97%
PLECOPTERA	51	20.56%
EPHEMEROPTERA	21	8.47%
EPHEMEROPTERA	11	4.44%
PLECOPTERA	10	4.03%
COLEOPTERA	6	2.42%
DIPTERR	6	2.42%
DIPTERA	4	1.61%
DIPTERA	3	1.214
PLECOPTERA	3	1.21%
DIPTERA	2	0.81%
EPHEMEROPTERA	2	0.81%
TRICHOPTERA	2	0.81%
COLEOPTERA	1	0.4%
DIPTERA	1	0.4%
COLEOPTERA	1	0.4%
DIPTERA	1	0.4%
DIPTERR	1	0.4%
EPHEMEROPTERA	1	0.4%
EPHEMEROPTERA	1	0.4%
DIPTEILR	1	0.4%
DIPTEILR	1	0.4%
DECAPODA	1	0.4%
OLIGOCHAETA	1	0.4%
TRICHOPTERA	1	0.4%

EQUITABILITY (Diversity due to spacies composition): 0.35

PERCENT CONTRIBUTION OF DOMINANT TAXON: Ephemerella sp. 114 45.97 %

FUNCTIONAL FEEDING GROUPS

Collector Gatherer.	118	47.58%
shredder..........	57	22.98%
Unknown............	41	16.53%
scraper............	23	9.27%
Predator...........	5	2.02%
collector Filterer.	4	1.61%
Piercer...........	0	00%

Water Body : Coles Fork
Date Placed :
Data Collected : 5/2/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLPCATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-11R	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	#M»	REPLIC 2 Count	#M»	REPLIC 3 Count	#M»	COMPOSITE Count	#M»
DIPTEFA	~~Tipula sp.~~	1	1					1	
DIPTEFA	Pseudolimnophila sp.	4	4					4	
DIPTERA	Cryptolabis sp.	3	3					3	
DIPTERA	Simulium sp.	28	28					28	
DIPTERA	Prosimulium sD.	1	1					1	
DIPTERA	Hemerodromia sp.	1	1					1	
DIPTERA	Undetermined	1	1					1	
DIPTERA	Helopelovia sp.	2	2					2	
DIPTERA	Parametriocnemus sp.	3	3					3	
DIPTEFA	Lopescladius sp.	1	1					1	
DIPTERA	Demicryptochironomus sp.	1	1					1	
DIPTERA	Polypedilum sp.	1	1					1	
DECAPODA	Astacidae unid.	1	1					1	
COLEOPTERR	Helichus sp.	1	1					1	
COLEOPTERA	Optioservus sD.	4	4					4	
OLIGOCHAETA	Lumbriculidae unid.	1	1					1	
COLEOPTERA	Sciara sp.	4	4					4	
EPHEMEROPTERA	Baetidae (2 tails)	43	43					43	
EPHEMEROPTERA	Baetidae (3 tailed/hind wing pad)	(10	10					10	
EPHEMEROPTERA	Ephemerella sp.	46	46					46	
EPHEMEROPTERA	Drunella sp.	19	19					19	
EPHEMEROPTERA	Epeorus sp.	2	2					2	
EPHEMEROPTERA	Cinygmula sp.	3	3					3	
PLECOPTBRA	Leuctridae/Capniidae (immature)	22	22					22	
PLECOPTERA	Allocapnia sp.	1	1					1	
PLECOPTERA	Amphinemura sp.	32	33					32	
PLECOPTERA	Isoperla sD.	17	7					7	
PLECOPTERA	Yugus sp.	1	1					1	
PLECOPTERA	Remenus sP.	1	1					1	
TRICHOPTERA	Diplectrona sD.	1	1					1	
TRICHOPTERA	Rhyacophila sp.	2	2					2	
DTPTERA	Potthastia sp.	1	1					1	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
MACROINVERTEBRATE	TOTALS:	249	249	0	0	0	0	249	0
BIOLOGY DATA SHEET	# OF TAXA:	32		0		0		32	
	DIVERSITY INDEX:		3.71		0		0		3.71

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Coles Fork
Date Placed : Date Collected : 5/2/00
Collector : Maudsley/Ackerman Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-11R	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 2	6.25%	CLASS I INDIV.	: 30	12.05%
CLASS II SPECIES	: 1	3.13%	CLASS TI INDIV.:	46	18.47%
CLASS III SPECPES:	3	9.33%	CLASS III INDIV:	37	14.36%
CLASS IV SPECIES	: 2	6.25%	CLASS IV INDIV.:	a	.8%
CLASS v SPECIES	: 24	75%	CLASS V INDIV.	: 134	53.82%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	32	5	5
EPT INDEX	14	3	5
% CONTRIBUTION OF DOMINANT TAXON	18.47 %	3	3
FLORIDA INDEX	5	3	1
% DIPTERA	19.28 %	3	3
% COLLECTOR-FILTERERS	11.65 %	5	5
% SHREDDERS	13.25 %	3	3
% CRUSTACEANS AND MOLLUSKS	.4 %	1	---
# CRUSTACEANS AND MOLLUSKS	1	1	---
SCORES		27	25
EVALUATION		No Impairment	No Impairment

Water Body : Coles Fork
Date Placed :
Date Collected : 5/2/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample *Mechanism:*

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-11M	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	#M»	REPLIC 2 Count	#M»	REPLIC 3 Count	#M»	COMPOSITE Count	#M»
DIPTERA	*Tipula sp.*	4	4					4	
DIPTEFA	*Helopelopia sp.*	1	1					1	
DIPTERA	*Phaenopsectra punctipes gp.*	1	1					1	
DIPTEFA	*Tribelos jacundum*	2	2					2	
DIPTERA	*Polypedilum fallax*	1	1					1	
ODONATX	*Boyeria sp.*	1	1					1	
COLEOPTERA	*Psephenus sp.*	1	1					1	
COLEOPTERA	*Helichus sp.*	3	3					3	
COLEOPTERA	*Hydroporus sp.*	2	2					2	
MOLLUSCA	*Musculium SD.*	1	1					1	
OLIGOCHAETA	*Lumbriculidae mid.*	1	1					1	
EPHEMEROPTERA	*Baetidae (2 tails)*	3	3					3	
EPHEMEROPTERA	*Baetidae (3 tailed/hind wins pad)*	1	1					1	
EPHEMEROPTERA	*Ephemerella sp.*	15	15					15	
EPHEMEROPTERA	*Eurylophella SD.*	38	38					38	
EPHEMEROPTERA	*Cinygmula sp.*	1	1					1	
PLECOPTERA	*Amphinemura sp.*	10	10					10	
PLECOPTERA	*Isoperla sp.*	2	2					2	
PLECOPTERA	*Remenus sp.*	1	1					1	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
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								0	
								0	
								0	
MACROINVERTEBRATE	TOTALS:	89	89	0	0	0	0	89	0
BIOLOGY DATA SHEET	# OF TAXA:	19		0		0		19	
	DIVERSITY PNDEX:		2.94		0		0		2.94

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Coles Fork
Date Placed :
Collector' : Maudsley/Ackerman
Identified By: Smith/Schultz/Foster
Date Collected : 5/2/00
Sorted By : Howard/Berrang
Sample Hechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-11M	Sample #:	Sample #:	Bottom:

CLASS I SPECIES :	1	5.26%	CLASS I INDIV. :	1	1.12%
CLASS II SPECIES :	1	5.26%	CLASS II INDIV.:	15	16.85%
CLASS III SPECIES:	3	15.79%	CLASS III INDIV:	12	13.48%
CLASS IV SPECIES :	3	15.79%	CLASS IV INDIV.:	9	10.11%
CLASS V SPECIES :	11	57.99%	CLASS V INDIV. :	52	58.43%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	19	3	3
EPT INDEX	8	3	5
% CONTRIBUTION OF DOMINANT TAXON	42.7 %	1	1
FLORIDA INDEX	3	1	1
% DIPTERA	10.11 %	3	3
% COLLECTOR-FILTERERS	1.12 %	1	1
% SHREDDERS	16.85 %	3	3
% CRUSTACEANS AND MOLLUSKS	1.12 %	1	---
# CRUSTACEANS AND MOLLUSKS	1	1	---
SCORES		17	17
EVALUATION		Moderate Impairment	Moderate Impairment

COMMUNITY DISTRIBUTION REPORT

water Body : Coles Fork
Date Placed :
Date Collected : 5/2/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE I	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-11M	Sample #:	Sample #:	Bottom:

	Total	% of Sample
EPHEMEROPTERA	38	42.7%
EPHEMEROPTERA	15	16.85%
PLECOPTERA	10	11.24%
DIPTERA	4	4.49%
COLEOPTERA	3	3.31%
EPHEMEROPTERA	3	3.37%
COLEOPTERA	2	2.25%
DIPTERR	2	2.25%
PLECOPTERA	2	2.25%
MOLLUSCA	1	1.12%
OLIGOCHAETA	1	1.12%
ODONATA	1	1.12%
EPHEMEROPTERA	1	1.12%
DIPTERA	1	1.12%
DIPTERR	1	1.12%
EPPEMEROPTERA	1	1.12%
DIPTERA	1	1.12%
COLEOPTERA	1	1.12%
PLECOPTERA	1	1.12%

EQUITABILITY (Diversity due to species composition): 0.58

PERCENT CONTRIBUTION OF DOMINANT TAXON: Eurylophella sp. 38 42.7 %

FUNCTIONAL FEEDING GROUPS

scraper.............	38	42.1%
collector Gatherer.	19	21.35%
Unknown............	15	16.85%
Shredder...........	15	16.85%
Predator...........	1	1.12%
Collector Filterer.	1	1.12%
Piercer............	0	00%

Water Body : Big Double
Date Placed :
collector : Maudsley/Ackerman
Identified By: Smith/Schultz/Foster

Date Collected : 5/3/00
Sorted By : Howard/Berrang
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	*Depth* :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-12M	Sample #:	Sample #:	Bottom:

	ORGANISMS	REPLIC 1 Count	#M»	REPLIC 2 Count	#Ma	*REPLIC* 3 Count	#M»	COMPOSITE Count	#M»
DIPTERA	*Tipula sp.*	2	2					2	
DIPTERA	*Conchapelopia sp.*	1	1					1	
DIPTERA	*Thienemanniella xena type*	2	2					2	
DIPTERA	Tvetenia bavarica *gp.*	1	1					1	
DIPTERA	*Parametriocnemus sp.*	6	6					6	
DIPTERA	*Polypedilum fallax*	4	4					4	
DECAPODA	*Astacidae unid.*	2	2					2	
COLEOPTERA	*Psephenus sp.*	6	6					6	
COLEOPTERA	*Helichus sp.*	1	1					1	
COLEOPTERA	*Optioservus su.*	1	1					1	
EPHEMEROPTERA	**Baetidae** *(2* **tails)**	10	10					10	
EPHEMEROPTERA	**Waetidac** *unid. (3 tails,hindwing)*	23	23					23	
EPHEMEROPTERA	*Ephemerella sp.*	21	21					21	
EPHEMEROPTERA	*Eurylophella sp.*	75	75					75	
EPHEMEROPTERA	*Isonychia sp.*	1	1					1	
EPHEMEROPTERA	*Ameletus sp.*	23	23					23	
PLECOPTERA	*Leuctridae/Capniidae (immature)*	1	1					1	
PLECOPTERA	*Amphinemura 3D.*	20	20					20	
PLECOPTERA	*Acroneuria sp.*	1	1					1	
PLECOPTERA	*Isoperla sp.*	3	3					3	
PLECOPTERA	*Diploperla sp.*	8	8					8	
PLECOPTERA	*Remenus sp.*	1	1					1	
PLECOPTERA	*4th qenus-unknown* b/c *immature*	2	2					2	
TRICHOPTERA	*Lepidostoma sp.*	3	3					3	
TRICHOPTERA	*Neophylax sD.*	1	1					1	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	

		REPLIC 1		REPLIC 2		REPLIC 3		COMPOSITE	
MACROINVERTEBRATE	TOTALS:	219	219	0	0	0	0	213	0
BIOLOGY DATA SHEET	# *OF* TAXA:	25		0		0		25	
	DIVERSITY INDEX:		3.36		0		0		3.36

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Big Double
Date Placed :
Date Collected : 5/3/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-12M	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	3	12%	CLASS I INDIV.	9	4.11%
CLASS II SPECIES	2	8%	CLASS II INDIV.	22	10.05%
CLASS III SPECIES	3	12%	CLASS III INDIV	27	12.33%
CLASS IV SPECIES	2	8%	CLASS IV INDIV.	3	1.37%
CLASS V SPECIES	15	60%	CLASS V INDIV.	158	72.15%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	25	3	3
EPT INDEX	15	3	5
% CONTRIBUTION OF DOMINANT TAXON	34.25 %	3	1
FLORIDA INDEX	8	5	1
% DIPTERA	7.31 %	3	3
% COLLECTOR-FILTERERS	0 %	1	1
% SHREDDERS	13.24 %	3	3
% CRUSTACEANS AND MOLLUSKS	.91 %	1	---
# CRUSTACEANS AND MOLLUSKS	1	1	---
SCORES		23	17 .
EVALUATION		Moderate Impairment	Moderate Impairment

COMMUNITY DISTRIBUTION REPORT

Water Body'. : Big Double
Date Placed :
Date Collected : 5/3/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Barrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-12M	Sample #:	Sample #:	Bottom:

	Total	% of Sample
EPHEMEROPTERA	75	34.25%
EPHEMEROPTERA	23	10.5%
EPHEMEROPTERA	23	10.51
EPHEMEROPTERA	21	9.59%
PLECOPTERA	20	9.13%
EPHEMEROPTERA	10	4.57%
PLECOPTERA	8	3.65%
COLEOPTEILA	6	2.74%
DIPTERA	6	2.74%
DIPTERA	4	1.83%
PLECOPTERA	3	1.37%
TRICHOPTERA	3	1.37%
DIPTERA	2	0.91%
DIPTERA	2	0.91%
DECAPODA	2	0.91%
PLECOPTERA	2	0.91%
PLECOPTERA	1	0.46%
COLEOPTERA	1	0.46%
PLECOPTERA	1	0.46%
COLEOPTERR	1	0.46%
EPHEMEROPTERA	1	0.46%
PLECOPTERA	1	0.46%
DIPTERA	1	0.46%
DIPTERA	1	0.46%
TRICHOPTERA	1	0.46%

EQUITABILITY (Diversity due *to* species composition): 0.60

PERCENT CONTRIBUTION OF DOMINANT TAXON: Eurylophella sp. 75 34.25 %

FUNCTIONAL FEEDING GROUPS

Unknown............	80	36.53%
Scraper............	76	34.7%
Collector Gatherer.	30	13.7%
shredder...........	29	13.24%
Predator...........	4	1.83%
Collector Filterer.	0	00%
Piercer............	0	00%

Water Body : **Big Double**
Date Placed : | Date Collected : 5/3/00
Collector : Maudsley/Ackerman | Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster | Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-12R	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	#M»	REPLIC 2 Count	#M»	REPLIC 3 Count	#M»	COMPOSITE Count	#M»
DIPTEFA	*Hexatoma sp.*	1	1					1	
DIPTERA	*Simulium sp.*	1	1					1	
DIPTEFA	*Helopelopia sp.*	1	1					1	
DIPTEFA	*Eukiefferiella sp.*	2	2					2	
DIPTERA	*Chaetocladius sp.*	1	1					1	
DTPTERA	*Tvetenia bavarica gp.*	1	1					1	
DIPTERA	*Orthocladius sp.*	1	1					1	
DIPTERA	*Polypedilum fallax*	1	1					1	
DECAPODA	*Astacidae unid.*	2	2					2	
COLEOPTERA	~~*Psephenus sp.*~~	4	4					4	
COLEOPTERA	~~*Helichus sp.*~~	2	2					2	
OLIGOCHAETA	*Nais sp.*	1	1					1	
EPHEMEROPTERA	~~Baetidae (2 tails)~~	36	36					36	
EPHEMEROPTERA	~~Baetidae (3 tailed/hind wing pad)~~	25	25					25	
EPHEMEROPTERA	~~*Ephemerella sp.*~~	14	14					14	
EPHEMEROPTERA	*Eurylophella sp.*	2	2					2	
EPHEMEROPTERA	*Drunella sp.*	7	7					7	
EPHEMEROPTERA	*Epeorus sp.*	14	14					14	
EPHEMEROPTERA	~~*Cinygmula sp.*~~	16	16					16	
EPHEMEROPTERA	~~*Heptagenia sp.*~~	5	5					5	
EPHEMEROPTERA	~~*Isonychia sp.*~~	6	6					6	
EPHEMEROPTERA	*Habrophlebiodes/Paraleptophlebia*	5	5					5	
PLECOPTERA	~~*Leuctridae/Capniidae (immature)*~~	37	37					37	
PLECOPTERA	~~*Amphinemura sp.*~~	46	46					46	
PLECOPTERA	~~*Acroneuria sp.*~~	3	3					3	
PLECOPTEFA	~~*Isoperla sp.*~~	7	7					7	
PLECOPTERR	*Yugus sp.*	3	3					3	
PLECOPTERA	*Diploperla sp.*	8	8					8	
TRICHOPTERA	~~*Diplectrona sp.*~~	1	1					1	
TRICHOPTERA	~~*Agapetus sp.*~~	2	2					2	
TRICHOPTERA	*Rhyacophila sp.*	1	1					1	
TRICHOPTERA	~~*Neophylax sp.*~~	2	2					2	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
MACROINVERTEBRATE BIOLOGY DATA SHEET	TOTALS:	258	258	0	0	0	0	258	0
	# OF TAXA:	32		0		0		32	
	DIVERSITY INDEX:		3.94		0		0		3.94

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Big Double
Date Placed :
Date Collected : 5/3/00
collector : Maudsley/Ackerman
Sorted By : Howard/Barrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 3	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-12R	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 3	9.38%	CLASS I INDIV.	: 16	6.2%
CLASS II SPECIES	: 3	9.38%	CLASS II INDIV.:	21	8.14%
CLASS III SPECIES:	3	9.38%	CLASS III INDIV:	51	19.77%
CLASS TV SPECIES	: 1	3.13%	CLASS IV INDIV.:	2	.78%
CLASS V SPECIES	: 22	68.75%	CLASS V INDIV.	: 168	65.12%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	32	5	5
EPT INDEX	20	3	5
% CONTRIBUTION OF DOMINANT TAXON	17.83 %	3	3
FLORIDA INDEX	9	5	3
% DIPTERA	3.49 %	3	3
% COLLECTOR-FILTERERS	.78 %	1	1
% SHREDDERS	18.22 %	3	3
% CRUSTACEANS AND MOLLUSKS	.78 %	1	---
# CRUSTACEANS AND MOLLUSKS	1	1	---
SCORES		25	23
EVALUATION		Moderate Impairment	No Impairment

Water Body : Sugar Creek
Date Placed :
Date Collected : 5/3/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-13R	Sample #:	sample #:	Bottom:

ORGANISMS		REPLIC 1 count	#M»	REPLIC 2 count	#M»	REPLIC 3 Count	#M»	COMPOSITE count	#M»
DIPTERA	Tipula sp.	13	3					3	
DIPTERA	Hexatoma sp.	1	1					1	
DIPTERA	Simulium sp.	2	2					2	
DIPTERA	Prosimulium sp.	1	1					1	
DIPTERA	Conchapelopia sp.	3	3					3	
DIPTERA	Helopelopia sp.	1	1					1	
DIPTERA	Parametriocnemus sp.	1	1					1	
DIPTERA	Eukiefferiella sp.	2	2					2	
DIPTERA	Polypedilum illinoense type	2	2					2	
COLEOPTERA	Psephenus sp.	1	1					1	
DECAPODA	Astacidae unid.	1	1					1	
COLEOPTERA	Ectopria sp.	1	1					1	
COLEOPTERA	Optioservus sp.	5	5					5	
EPHEMEROPTERA	Baetidae (2 tails)	41	41					41	
EPHEMEROPTERA	Baetidae (3 tailed/hind wing pad)	3	3					3	
EPHEMEROPTERA	Drunella sp.	47	47					47	
EPHEMEROPTERA	Serratella sp. (immature)	1	1					1	
EPHEMEROPTERA	Heptageniidae unid. (damaged)	1	1					1	
EPHEMEROPTERA	Epeorus sp.	16	16					16	
EPHEMEROPTERA	Cinygmula sp.	26	26					26	
EPHEMEROPTERA	3rd genus (damaged)	1	1					1	
EPHEMEROPTERA	Leptophlebiidae unid.	2	2					2	
EPHEMEROPTERA	Ameletus sp.	15	5					5	
EPHEMEROPTERA	Unknown	1	1					1	
PLECOPTERA	Allocapnia sp. (immature)	21	21					21	
PLECOPTERA	Amphinemura	23	23					23	
PLECOPTERA	Remenus sp.	1	1					1	
PLECOPTERA	Yugus sp.	1	1					1	
PLECOPTERA	Diploperla sp.	1	1					1	
PLECOPTERA	Pteronarcys sp.	2	2					2	
TRICHOPTERA	Agapetus sp.	5	5					5	
EPHEMEROPTERA	Ephemerella sp.	6	6					6	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
MACROINVERTEBRATE	TOTALS:	228	228	0	0	0	0	228	0
BIOLOGY DATA SHEET	# OF TAXA:	32		0		0		32	
	DIVERSITY INDEX:		3.72		0		0		3.72

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MACROINVERTEBRATE SUMMARY REPORT

Water Body : Sugar Creek
Date Placed : Date Collected : 5/3/00
Collector : Maudsley/Ackerman Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 3	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-13R	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 3	9.38%	CLASS I INDIV.	: 20	8.77%
CLASS II SPECIES	: 1	3.13%	CLASS II INDIV.:	6	2.63%
CLASS 111 SPECIES:	3	9.38%	CLASS III INDIV:	23	12.72%
CLASS IV SPECIES	: 2	6.25%	CLASS IV INDIV.:	4	1.75%
CLASS V SPECIES	: 23	71.88%	CLASS V INDIV.	: 169	74.12%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	32	5	5
EPT INDEX	19	3	5
% CONTRIBUTION OF DOMINANT TAXON	20.61 %	3	1
FLORIDA INDEX	7	5	1
% DIPTERA	7.02 %	3	3
% COLLECTOR-FILTERERS	.88 %	1	1
% SHREDDERS	12.28 %	1	3
% CRUSTACEANS AND MOLLUSKS	.44 %	1	---
# CRUSTACEANS AND MOLLUSKS	1	1	---
SCOPES		23	19
EVALUATION		Moderate Impairment	Wodcrate Impairment

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Water Body : Sugar Creek
Date Placed :
Date Collected : 5/3/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-13M	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 count	REPLIC 1 #M»	REPLIC 2 Count	REPLIC 2 #M»	REPLIC 3 count	REPLIC 3 #M»	COMPOSITE Count	COMPOSITE #M»
DIPTERA	Simulium sp.	12	12					12	
DIPTEFA	Prosimulium sp.	2	2					2	
DIPTERA	Ormosia sp.	1	1					1	
DIPTERA	Corynoneura sp.	2	2					2	
DIPTERA	Parametriocnemus sp.	7	7					7	
DIPTEFA	Eukiefferiella sp.	1	1					1	
DIPTERA	Tvetenia bavarica gp.	2	2					2	
DIPTERA	Stilocladius sp.	2	2					2	
DIPTERA	Cryptochironomus sp.	1	1					1	
DIPTERA	Tanytarsus sp.	1	1					1	
ODONATA	Calopteryx sp.	1	1					1	
DECAPODA	Astacidae unid.	1	1					1	
COLEOPTERA	Helichus sp.	1	1					1	
COLEOPTERA	Tropisternus sp.	1	1					1	
DIPTERA	Muscidae unidentified	1	1					1	
EPHEMEROPTERA	Baetidae (2 tails,immature)	9	9					9	
EPHEMEROPTERA	Baetidae unid. 13 tails,hindwing)	1	1					1	
EPHEMEROPTERA	Eurylophella sp.	17	17					17	
EPHEMEROPTERA	Drunella sp.	3	3					3	
EPHEMEROPTERA	Ephemerella sp.	8	8					8	
EPHEMEROPTERA	unknown mature	1	1					1	
EPHEMEROPTERA	Epeorus sp.	8	8					8	
EPHEMEROPTERA	Leucrocuta sp./Nixe sp. (?)	1	1					1	
EPHEMEROPTERA	Leptophlebiidae unid.	1	1					1	
EPHEMEROPTERA	Caenis sp.	1	1					1	
EPHEMEROPTERA	Ameletus sp.	9	9					9	
PLECOPTERA	Amphinemura sp.	36	36					36	
PLECOPTERA	Isoperla sp.	4	4					4	
PLECOPTERR	Diploperla sp.	9	9					9	
PLECOPTERA	Pteronarcys sp.	1	1					1	
TRICHOPTERA	Cheumatopsyche sp.	1	1					1	
TRICHOPTERA	Neophylax sp.	3	3					3	
TRICHOPTERA	Lepidostoma sp.	1	1					1	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
MACROINVERTEBRATE BIOLOGY DATA SHEET	TOTALS:	150	150	0	0	0	0	150	0
	# OF TAXA:	33		0		0		33	
	DIVERSITY INDEX:		4.05		0		0		4.05

MACROINVERTEBRATE SUMMARY REPORT

water Body : Sugar Cfeek
Date Placed :
collector : Maudsley/Ackerman
Identified By: Smith/Schultz/Foster

Date Collected : 5/3/00
Sorted By : Howard/Berrang
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-13M	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 6	18.18%	CLASS I INDIV.	: 25	16.67%
CLASS II SPECIES	: 3	9.09%	CLASS II INDIV.:	12	8%
CLASS III SPECIES:	3	9.09%	CLASS III INDIV:	38	25.33%
CLASS IV SPECIES	: 2	6.06%	CLASS IV INDIV.:	2	1.33%
CLASS V SPECIES	: 19	57.58%	CLASS V INDIV.	: 73	48.67%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS1

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	33	5	5
EPT INDEX	18	3	5
% CONTRIBUTION OF DOMINANT TAXON	24 %	3	1
FLORIDA INDEX	15	5	3
% DIPTERA	21.33 %	3	3
% COLLECTOR-FILTERERS	9.33 %	5	3
% SHREDDERS	25.33 %	3	3
% CRUSTACEANS AND MOLLUSKS	.67 %	1	n--
# CRUSTACEANS AND MOLLUSKS	1	1	--
SCORES		29	23
EVALUATION	No Impairment		No Impairment

Water Body : Sugar Creek, Clay County, KY
uate Placed. :
Date collected : 5/3/00
collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-13R-D	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLTC 1 Count	#M»	REPLIC 2 Count	#M»	REPLJC 3 Count	#M»	COMPOSITE Count	#M»
DIPTERA	Simulium sp.	25	25					25	
DIPTERA	Procimulium sp.	1249	249					249	
DLPTERA	Hexatoma sP.	5	5					5	
DIPTERA	Helopelopia sp.	1	1					1	
DIPTERA	Stilocladius sp.	1	1					1	
DIPTERA	Eukiefferiella sp.	3	3					3	
DIPTERA	Parakiefferiella sp.	2	2					2	
COLEOPTERA	Psephenus sp.	9	9					9	
COLEOPTERA	Helichus sp.	1	1					1	
COLEOPTERA	Stenelmis sp.	1	1					1	
COLEOPTERA	Optioservus sp.	10	10					10	
COLEOPTERA	Ectopria sp.	2	2					2	
EPHEMEROPTERA	Baetidae (2 tails)	66	66					66	
EPHEMEROPTERA	Ephemerella sp.	6	6					6	
EPHEMEROPTERA	Eurylophella SP.	1	1					1	
EPHEMEROPTERA	Drunella sp.	53	53					53	
EPHEMEROPTERA	Epeorus sp.	52	52					52	
EPHEMEROPTERA	Cinygmula sp.	45	45					45	
EPHEMEROPTERA	Isonychia sp.	20	20					20	
EPHEMEROPTERA	Ameletus sp.	4	4					4	
PLECOPTERA	Leuctridae/Capniidae (immature)	16	16					16	
PLECOPTERA	Amphinemura sp.	51	51					51	
PLECOPTERA	Acroneuria sp.	4	4					4	
PLECOPTERA	Yugus SD.	2	2					2	
PLECOPTERA	Remenus sp.	2	2					2	
PLECOPTERA	Unknown (damaged)	1	1					1	
PLECOPTERA	Pteronarcys sp.	13	13					13	
TRICHOPTERA	Rhyacophila sp.	2	2					2	
TRICHOPTERA	Neophylax SD.	18	18					18	
TRICHOPTERA	Lepidostoma sp.	1	1					1	
DIPTERA	Simuliidae umid.(larva)	2	2					2	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	

MACROINVERTEBRATE BIOLOGY DATA SHEET								
TOTALS:	668	668	0	0	0	0	668	0
# OF TAXA:	31		0		0		31	
DIVERSITY INDEX:		3.35		0		0		3.35

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MACROINVERTEBRATE SUMMARY REPORT

Water Body : Sugar Creek, Clay County, KY
Date placed : | Date Collected : 5/3/00
Collector : Maudsley/Ackerman | Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster | Sample Wechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
sample #: KYM-13R-D	Sample #:	Sample #:	Bcttom:

CLASS I SPECIES	: 4	12.9%	CLASS I INDIV.	: 91	13.62%
CLASS II SPECIES	: 2	6.45%	CLASS II INDIV.:	24	3.59%
CLASS III SPECIES:	3	9.68%	CLASS III INDIV:	70	10.48%
CLASS IV SPECIES	: 3	9.68%	CLASS IV INDIV.:	4	.6%
CLASS V SPECIES	: 19	61.29%	CLASS V INDIV.	: 479	71.71%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	31	5	5
EPT INDEX	18	3	5
% CONTRIBUTION OP DOMINANT TAXON	37.28 %	1	1
FLORIDA INDEX	10	5	3
% DIPTERA	43.11 %	1	1
% COLLECTOR-FILTERERS	3.74 %	3	1
% SHREDDERS	9.73 %	1	3
% CRUSTACEANS AND MOLLUSKS	0 %	1	---
# CRUSTACEANS AND MOLLUSKS	0	1	---
SCORES		21	19
EVALUATION		Moderate Impairment	Moderate Impairment

Water Body : Sugar creek
Date Placed :
Date Collected : 5/3/00
collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-13M-D	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	#M»	REPLIC 2 Count	#M»	REPLIC 3 Count	#M»	COMPOSITE Count	#M»
DIPTERA	*Simulium sp.*	4	4					4	
DIPTERA	*Prosimulium sp.*	7	7					7	
DIPTERA	*Helius sp.*	1	1					1	
DIPTERA	*Helopelopia sp.*	2	2					2	
DIPTERA	*Eukiefferiella sp.*	2	2					2	
DIPTERA	*Polypedilum illinoense*	2	2					2	
HEMIPTERA	*Trepobates sp.*	1	1					1	
DECAPODA	Astacidae unid.	4	4					4	
MOLLUSCA	*Musculium sp.*	1	1					1	
ODONATA	*Calopteryx sp.*	1	1					1	
ODONATA	Libellulidae unid.	1	1					1	
COLEOPTERA	*Psephenus sp.*	1	1					1	
COLEOPTERA	*Helichus sp.*	2	2					2	
COLEOPTERA	*Optioservus sp.*	1	1					1	
EPHEMEROPTERA	Baetidae (2 tails)	3	3					3	
EPHEMEROPTERA	*Ephemerella sp.*	5	5					5	
EPHEMEROPTERA	*Eurylophella sp.*	8	8					8	
EPHEMEROPTERA	*Drunella sp.*	1	1					1	
EPHEMEROPTERA	*Habrophlebia sp.*	3	3					3	
EPHEMEROPTERA	*Ameletus sp.*	28	28					28	
PLECOPTERA	*Amphinemura sp.*	21	21					21	
PLECOPTERA	*Isoperla sp.*	1	1					1	
PLECOPTERA	*Peltoperla sp.*	1	1					1	
TRICHOPTERA	*Pycnopsyche sp.*	1	1					1	
TRICHOPTERA	*Lepidostoma sp.*	2	2					2	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
TOTALS:		104	104	0	0	0	0	104	0
# OF TAXA:		25		0		0		25	
DIVERSITY INDEX:			3.65		0		0		3.65

MACROINVERTEBRATE BIOLOGY DATA SHEET

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Sugar Creek
Date placed :
Collector : Maudsley/Ackerman
Identified By: Smith/Schultz/Foster
Date Collected : 5/3/00
Sorted By : Howard/Berrang
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-13M-D	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 3	12%	CLASS I INDIV.	: 7	6.73%
CLASS II SPECIES	: 1	4%	CLASS II INDIV.:	5	4.81%
CLASS III SPECIES:	4	16%	CLASS III INDIV:	24	23.08%
CLASS IV SPECIES	: 2	8%	CLASS IV INDIV.:	3	2.88%
CLASS V SPECIES	: 15	60%	CLASS V INDIV.	: 65	62 5%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	25	3	3
EPT INDEX	11	3	5
% CONTRIBUTION OF DOMINANT TAXON	26.92 %	3	1
FLORIDA INDEX	7	5	1
% DIPTERA	17.33. %	3	3
% COLLECTOR-FILTERERS	4.81 %	3	1
% SHREDDERS	22.12 %	3	3
% CRUSTACEANS AND MOLLUSKS	4.81 %	1	---
# CRUSTACEANS AND MOLLUSKS	2	1	---
SCORES		25	17
EVALUATION		moderate Impairment	Moderate Impairment

COMMUNITY DISTRIBUTION REPORT

Water Body. : Sugar *Creek*
Date Placed :
Date Collected : 5/3/00
Collector : Maudsley/Ackerman
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
sample #: KYM-13M-D	Sample #:	Sample #:	Bcttom:

	Total	% of sample
EPHEMEROPTERA	28	26.92%
PLECOPTERA	21	20.19%
EPHEMEROPTERA	8	7.69%
DIPTERA	7	6.73%
EPHEMEROPTERA	5	4.81%
DECAPODA	4	3.85%
DIPTERA	4	3.85%
EPHEMEROPTERA	3	2.88%
EPHEMEROPTERA	3	2.88%
COLEOPTERA	2	1.92%
DIPTERA	2	1.92%
DIPTERA	2	1.92%
DIPTERA	2	1.92%
TRICHOPTERA	2	1.92%
ODONATA	1	0.96%
COLEOPTERA	1	0.96%
DIPTERA	1	0.96%
EPHEMEROPTERA	1	0.96%
MOLLUSCA	1	0.96%
HEMIPTERA	1	0.96%
ODONATA	1	0.96%
PLECOPTERA	1	0.96%
PLECOPTERA	1	0.96%
TRICHOPTERA	1	0.96%
COLEOPTERA	1	0.96%

EQUITABILITY (Diversity due to species composition): 0.72

PERCENT CONTRIBUTION OF DOMINANT TAXON: Ameletus sp. 28 26.92 %

FUNCTIONAL FEEDING GROUPS

Unknown............	52	50% -
shredder...........	23	22.12%
Scraper............	9	8.65%
Predator...........	8	7.69%
Collector Gatherer.	7	6.73%
Collector Filterer.	5	4.81%
Piercer............	0	00%

Water Body : Lick Branch
Date Placed :
Date Collected
Collector : Howard/Weldon
sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-14R	Sample #:	sample #:	Bottom:

ORGANISMS		KEPLIC 1 count	#M»	REPLIC 2 count	#M»	REPLIC 3 count	#M»	COMPOSITE count	#M»
DIPTERA	~~Hemerodromia sp.~~	17	17					17	
DIPTERA	Wiedemannia sp.	3	3					3	
DIPTERA	~~Conchapelopia sp.~~	1	1					1	
DIPTERA	~~Cricotopus trifascia~~	49	49					49	
DIPTERA	Orthocladius sp.	2	2					2	
DIPTERA	~~Eukiefferiella (2 spp.)~~	2	2					2	
DIPTERA	~~Metriocnemus fuscipes gp.~~	1	1					1	
OLIGOCHAETA	~~Lumbriculidae mid.~~	15	15					15	
ODONATA	~~Stylogomphus sp.~~	1	1					1	
COLEOPTERA	~~Stenelmis sp.~~	1	1					1	
MEGALOPTERA	~~Nigronia sp.~~	1	1					1	
PLECOPTERA	~~Amphinemura sp.~~	64	64					64	
TRICHOPTERA	~~Hydropsyche sp.~~	20	20					20	
TRICHOPTERA	~~Diplectrona sp.~~	1	1					1	
TRICHOPTERA	~~Cheumatopsyche sp.~~	1	1					1	
TRICHOPTERA	~~Hydroptila sp. (immatures)~~	9	9					9	
TRICHOPTERA	~~Chimarra sp.~~	9	9					9	
TRICHOPTERA	~~unknown pupa~~	1	1					1	
DIPTERA	~~Chironomidae (larval~~	2	2					2	
LEPIDOPTERA	~~Lepidoptera unid.~~	1	1					1	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
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								0	
								0	
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								0	
								0	
								0	

MACROINVERTEBRATE BIOLOGY DATA SHEET								
TOTALS:	201	201	0	0	0	0	201	0
# OF TAXA:	20		0		0		20	
DIVERSITY INDEX:		2.97		0		0		2.97

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Lick Branch
Date Placed : Date Collected :
Collector : Howard/Weldon Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster Sample mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
nepth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grab5 :	Grabs : 1
sample #: KYM-14R	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 2	10%	CLASS I INDIV.	: 29	14.43%
CWSS TI SPECIES	: 1	5%	CLASS II INDIV.	: 1	.5%
CLASS III SPECIES	: 2	10%	CLASS III INDIV	: 79	39.3%
CLASS IV SPECIES	: 1	5%	CLASS IV INDIV.	: 1	.5?:
CLASS V SPECIES	: 14	70%.	CLASS V INDIV.	: 91	45.27%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	20	3	3
EPT INDEX	7	3	5
% CONTRIBUTION OF DOMINANT TAXON	31.84 %	3	1
FLORIDA INDEX	5	3	1
% DIPTERA	38.31 %	1	1
% COLLECTOR-FILTERERS	15.42 %	5	5
% SHREDDERS	32.34 %	3	3
% CRUSTACEANS AND MOLLUSKS	0 %	1	---
# CRUSTACEANS AND MOLLUSKS	0	1	---
SCORES		23	19
EVALUATION		Moderate Impairment	Moderate.Impairment

COMMUNITY DISTRIBUTION REPORT

Water Body : Lick Branch
Date Placed : Date Collected :
Collector : Howard/Weldon Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-14R	Sample #:	Sample #:	Bottom:

	Total	% of Sample
PLECOPTERA	64	31.84%
DIPTERA	49	24.38%
TRICHOPTERA	20	9.95%
DIFTERA	17	8.46%
OLIGOCHAETA	15	7.46%
TRICHOPTERA	9	4.48%
TRICHOPTERA	9	4.48%
DIPTERA	3	1.49%
DIPTERA	2	1%
DIPTERA	2	1%
DIPTERA	2	1%
ODONATA	1	0.5%
DIPTERA	1	0.5%
TRICHOPTERA	1	0.5%
TRICHOPTERA	1	0.5%
COLEOPTERA	1	0.5%
DIPTERA	1	0.5%
TRICHOPTERA	1	0.5%
MEGALOPTERA	1	0.5%
LEPIDOPTERA	1	0.5%

EQUITABILITY *(Diversity* due *to* species composition): 0.55

PERCENT CONTRIBUTION OF DOMINANT TAXON: Amphinemura sp. 64 31.84 %

FUNCTIONAL FEEDING GROUPS

Unknown............	71	35.32%
Shredder...	65	32.34%
Collector Filterer.	31	15.42%
Predator...........	19	9.45%
Collector Gatherer.	15	7.46%
Scraper............	0	00%
Fiercer...	0	00%

Water Body : Lick Branch
Date Placed :
collector : Howard/Weldon
Identified By: Smith/Schultz/Foster
Date Collected : 5/4/00
Sorted By : Howard/Berrang
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-14M	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 count	REPLIC 1 #M»	REPLIC 2 count	REPLIC 2 #M»	REPLIC 3 count	REPLIC 3 #M»	COMPOSITE count	COMPOSITE #M»
DIPTERA	~~*Culiciodes sp. (?)*~~	1	1					1	
DIPTERA	*Conchapelopia sp.*	1	1					1	
DTPTERA	*Meropelopia sp.*	1	1					1	
DIPTERA	*Cricotopus sp.*	1	1					1	
DIPTERA	Osthocladius *sp. (2 spp.?)*	8	8					8	
DIPTERA	*Tanytarsus sp.*	1	1					1	
NEUROPTERA	*Sialis sp.*	1	1					1	
OLIGOCHAETA	*Limnodrilus* sD.	1	1					1	
OLIGOCHAETA	*Tubificidae unid.*	1	1					1	
PLECOPTERA	*Amphinemura sp.*	3	3					3	
TRICHOPTERA	*Hydroptila sp.*	(13	13					13	
TRICHOPTERA	*Triaenodes sp.*	1	1					1	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
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								0	
								0	
								0	
								0	
								0	
MACROINVERTEBRATE	TOTALS:	33	33	0	0	0	0	33	0
BIOLOGY DATA SHEET	# OF TAXA:	1.2		0		0		12	
	DIVERSITY INDEX:		2.72		0		0		2.72

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MACROINVERTEBRATE SUMMARY REPORT

Water Body : Lick Branch
Date Placed :
Date Collected : 5/4/00
collector : Howard/Weldon
sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE I	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : I	Grab6 :	Grabs :	Grabs : 1
Sample #: KYM-14M	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 1	8.33%	CLASS I INDIV.	: 13	39.39%
CLASS II SPECIES	: 1	8.33%	CLASS II INDIV.:	1	3.03%
CLASS III SPECIES:	3	25%	CLASS III INDIV:	5	15.15%
CLASS IV SPECIES	: a	0%	CLASS IV INDIV.:	0	0%
CLASS V SPECIES	: 7	58.33%	CLASS V TNDIV.	: 14	42.42%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	12	1	1
EPT INDEX	3	1	1
% CONTRIBUTION OF DOMINANT TAXON	39.39 %	1	1
FLORIDA INDEX	3	1	1
% DIPTERA	39.39 %	1	1
% COLLECTOK-FILTERERS	3.03 %	1	1
% SHREDDERS	15.15 %	3	3
% CRUSTACEANS AND MOLLUSKS	0 %	1	---
# CRUSTACEANS AND MOLLUSKS	0	1	---
SCORES		11	9
EVALUATION		Severe Degradation	Severe Degradation

COMMUNITY DISTRIBUTION REPORT

Water Body : Lick Branch
Date Placed : Date Collected : 5/4/00
Collector : Howard/Weldon Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 3	Grabs :	Grabs :	Grab6 : 1
Sample I: KYM-14M	Sample #:	Sample #:	Bottom:

	Total	% of Sample
TRICHOPTERA	13	39.39%
DIPTERA	8	24.24%
PLECOPTERA	3	9.09%
DTPTERA	1	3.03%
DIPTERA	1	3.03%
DIPTERA	1	3.03%
NEUROPTERA	1	3.03%
OLIGOCHAETA	1	3.03%
OLIGOCHAETA	1	3.03%
DIPTERA	1	3.03%
DIPTERA	3	3.03%
TRICHOPTERA	1	3.03%

EQUITABILITY (Diversity due to species composition) : 0.75

PERCENT CONTRIBUTION OF DOMINANT TAXON: Hydroptila sp. 13 39.39 %

FUNCTIONAL FEEDING GROUPS

Piercer............	13	39.39%
unknown............	11	33.33%
Shredder::	5	15.15%
Collector Gatherer.	2	6.06%
Predator...........	1	3.03%
Collector Filterer.	1	3.03%
Scraper............	0	00%

Water Body : Lick Branch
Date Placed :
Date Collected : 5/4/00
Collector : Howard/Weldon
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
sample #: KYM-14R-D	Sample #:	Sample #:	Bottom:

ORGANISMS		REPLIC 1 Count	#M»	REPLIC 2 Count	#M»	REPLIC 3 Count	#M»	COMPOSITE Count	#M»
DIPTERA	*Hemerodromia sp.*	10	10					10	
DIPTERA	*Wiedemannia sp.*	12	12					12	
DIPTERA	*Undetermined*	2	2					2	
DIPTERA	*Larsia sp.*	1	1					1	
DIPTERA	*Conchapelopia sp.*	1	1					1	
DIPTERA	*Cricotopus sp.*	63	63					63	
DIPTERA	*Orthocladius sp.*	1	1					1	
DIPTERA	*Parametriocnemus sp.*	1	1					1	
DIPTERA	*Chaetocladius sp.*	1	1					1	
OLIGOCHAETA	*Lumbriculidae uaid.*	19	19					19	
MOLLUSCA	*Physella sp.*	1	1					1	
NEUROPTERA	*Nigronia sp.*	1	1					1	
COLEOPTERA	*Stenelmis sp.*	1	1					1	
PLECOPTERA	*Amphinemura sp.*	10	10					10	
TRICHOPTERA	*Hydropsyche sp.*	1	1					1	
TRICHOPTERA	*Hydroptila sp.*	77	77					77	
TRICHOPTERA	*Chimarra sp.*	4	4					4	
PLECOPTERA	*Soyedina sp.*	1	1					1	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
								0	
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								0	
								0	
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								0	
								0	
								0	
								0	
MACROINVERTEBRATE	TOTALS:	207	207	0	0	0	0	207	0
BIOLOGY DATA SHEET	# OF TAXA:	18		0		0		18	
	DIVERSITY INDEX:		2.58		0		0		2.58

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Lick Branch
Date. Placed :
Date Collected : 5/4/00
Collector : Howard/Weldon
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-14R-D	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 3	16.67%	CLASS I INDIV.	: 82	39.61%
CLASS II SPECIES	: 1	5.56%	CLASS II INDIV.:	63	30.43%
CLASS III SPECIES:	3	16.67%	CLASS III INDIV:	30	14.494
CLASS IV SPECIES :	1	5.56%	CLASS IV INDIV.:	1	.48%
CLASS V SPECIES	: 10	55.56%	CLASS V INDIV.	: 31.	14.98%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	18	3	3
EPT INDEX	5	3	3
% CONTRIBUTION OF DOMINANT TAXON	37.2 %	1	1
FLORIDA INDEX	7	5	1
% DIPTERA	44.44 %	1	1
% COLLECTOR-FILTERERS	2.42 %	1	1
% SHREDDERS	35.27 %	3	3
% CRUSTACEANS AND MOLLUSKS	.48 %	1	---
# CRUSTACEANS AND MOLLUSKS	1	1	---
SCORES		19	13
EVALUATION		Moderate Impairment	Severe Degradation

COMMUNITY DISTRIBUTION REPORT

Water Body	: Lick Branch		
Date Placed	:	Date Collected	: 5/4/00
Collector	: Howard/Weldon	Sorted By	: Howard/Berrang
Identified By:	Smith/Schultz/Foster	Sample Mechanism:	

REPLICATE 1	REPLICATE 2	REPLICATE 3	COWPOSTTE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-14R-D	Sample #:	Sample #:	Bcttom:

	Total	% of Sample
TRICHOPTERA	71	37.2%
DIPTERA	63	30.43%
OLIGOCHAETA	19	9.18%
DIPTERA	12	5.8%
PLECOPTERA	10	4.83%
DTPTERA	10	4.83%
TRICHOPTERA	4	1.93%
DIPTERA	2	0.37%
DIPTERA	1	0.48%
DIPTERA	1	0.48%
MOLLUSCA	1	0.48%
NEUROPTERA	1	0.48%
COLEOPTERA	1	0.48%
DIPTERA	1	0.48%
TRICHOPTERA	1	0.48%
DIPTERA	1	0.48%
DIPTERA	1	0.48%
PLECOPTERA	1	0.48%

EQUITABILITY (Diversity due to species composition): 0.44

PERCENT CONTRIBUTION OF DOMINANT TAXON: Hydroptila sp. 77 37.2 %

FUNCTIONAL FEEDING GROUPS

Piercer............	77	37.2%
Shredder...........	73	35.27%
Unknown............	20	9.66%
Collector Gatherer.	19	9.18%
Predator...	12	5.8%
Collector Filterer.	5	2.42%
Scraper..	1	0.48%

water Body : Lick Branch
Date Placed : 3
Collector : Howard/Weldon
Identified By: Smith/Schultz/Foster

Date collected : 5/4/00
sorted BY : Howard/Berrang
sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLICATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth. :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-14M-D	Sample #:	Sample #:	Bottom:

	ORGANISMS	REPLIC 1 Count	REPLIC 1 #M»	REPLIC 2 Count	REPLIC 2 #M»	REPLIC 3 Count	REPLIC 3 #M»	COMPOSITE Count	COMPOSITE #M»
HEMIPTERA	*Microvelia sp.*	1	1					1	
DIPTERA	*Atrichopogon* SD.	1	1					1	
DIPTERA	*Cricotopus trifascia*	6	6					6	
DIPTERA	*Orthocladius sp.*	1	1					1	
DECAPODA	*Astacidae unid.*	1	1					1	
OLIGOCHAETA	*Limnodrilus* SD.	1	1					1	
OLIGOCHAETA	*Tubificidae unid.*	1	1					1	
PLECOPTEKA	*Amphinemura sp.*	3	3					3	
TRICHOPTERA	*Hydroptila sp.*	7	7					7	
								0	
								0	
								0	
								0	
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	TOTALS:	22	22	0	0	0	0	22	0
	# OF TAXA:	9		0		0		9	
	DIVERSITY INDEX:		2.64		0		0		2.64

MACROINVERTEBRATE
BIOLOGY DATA SHEET

7Y

MACROINVERTEBRATE SUMMARY REPORT

Water Body : Lick Branch
Date Placed :
Date Collected : 5/4/00
Collector : Howard/Weldon
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLTCATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-14M-D	Sample #:	Sample #:	Bottom:

CLASS I SPECIES	: 1	11.11%	CLASS I INDIV.	: 7	31.82%
CLASS II SPECIES	: 0	0%	CLASS I1 INDIV.	: 0	0%
CLASS III SPECIES	: 4	44.44%	CLASS III INDIV	: 6	21.27%
CLASS IV SPECIES	: 1	11.11%	CLASS IV INDIV.	: 1	4.85%
CLASS V SPECIES	: 3	33.33%	CLASS V INDIV.	: 8	36.36%

INVERTEBRATE BIOLOGICAL INDEX for STREAMS (IBIS)

	VALUE	PENINSULA SCORE	PANHANDLE SCORE
NUMBER OF TAXA	9	1	1
EPT INDEX	2	1	1
% CONTRIBUTION OF DOMINANT TAXON	31.82 %	3	1
FLORIDA INDEX	2	1	1
4 DIPTERA	36.36 %	1	3
% COLLECTOR-FILTERERS	0 %	1	1
% SHREDDERS	13.64 %	3	3
% CRUSTACEANS AND MOLLUSKS	4.55 %	1	---
# CRUSTACEANS AND MOLLUSKS	1	1	---
SCORES		13	11
EVALUATION		Severe Degradation	Severe Degradation

W

COMMUNITY DISTRIBUTION REPORT

Water Body. : Lick, Branch
Date Placed :
Date Collected : 5/4/00
Collector : Howard/Weldon
Sorted By : Howard/Berrang
Identified By: Smith/Schultz/Foster
Sample Mechanism:

REPLICATE 1	REPLICATE 2	REPLTCATE 3	COMPOSITE
Factor: 1	Factor:	Factor:	
Depth :	Depth :	Depth :	
Grabs : 1	Grabs :	Grabs :	Grabs : 1
Sample #: KYM-14M-D	Sample #:	Sample #:	Bottom:

	Total	% of Sample
TRICHOPTERA	7	31.82%
DIPTERA	6	27.21%
PLECOPTERA	3	13.64%
DIPTERA	1	4.55%
DECAPODA	1	4.55%
OLIGOCHAETA	1	4.55%
OLIGOCHAETA	1	4.55%
DIPTERA	1	4.55%
HEMIPTERA	1	4.55%

EQUITABILITY (Diversity due to species composition): 1.00

PERCENT CONTRIBUTION OF DOMINANT TAXON: Hydroptila sp. 7 31.82 %

FUNCTIONAL FEEDING GROUPS

Unknown............	7	31.82%
Piercer............	7	31.82%
Predator...........	3	13.64%
Shredder............	3	13.64%
Collector Gatherer.	2	9.09%
Scraper............	0	00%
Collector Filterer.	0	00%

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Long Fork	LOCATION @ Buckhorn cr. Rd
STATIONS 1 RIVERMILE	STREAM CLASS
LAT LONG	RIVER BASM
STORET#	AGENCY
INVESTIGATORS LD JM, JA SW	
FORM COMPLETED BY LD	TIME CM (PM) / REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags. submerged logs. undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but *not* yet prepared for colonization (may rare at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat: lack of habitat is obvious; substrate unstable or lacking.
SCORE 18	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel. cobble, and boulder panicles are 0-*25%* surrounded by tine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles arc 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE 18	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All iaur velocity/depth regimes present (slow-deep. slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE 17	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom aifected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently: pools almost absent due to substantial sediment deposition.
SCORE 15	20 19 18 17 16	(15) 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel: or <25% of channel substrate is exposed.	Water Ells 25-75% of the available channel. and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 18	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal		Poor
7. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 18	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25
SCORE 19	20 (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
9. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 8 (LB)	Left Bank 10 9	(8) 7 6	5 4 3	2 1 0
SCORE [illegible] (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 9 (LB)	Left Bank 10 (9)	8 7 6	5 4 3	2 1 0
SCORE 9 (RB)	Right Bank 10 (9)	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE 8 (LB)	Left Bank 10 9	(8) 7 6	5 4 3	2 1 0
SCORE 8 (RB)	Right Bank 10 9	(8) 7 6	5 4 3	2 1 0

Total Score 173

2

STREAM NAME Long Fork	LOCATION @ Buckhorn Cr. Rd
STATION # 1 RIVERMILE	STREAM CLASS
LAT LONG	RIVER BASIN
STORET #	AGMCY
INVESTIGATORS LD, JM, JA, SW	
FORM COMPLETED BY LD	DATE 5-2-00 AM (PM)	REASON FOR SURVEY

TE LOCATION/MAP	Draw a map of the site and indicate the areas sampled photo #3 up photo #4 down
HABITAT TYPES	*Indicate the percentage of each habitat type present* ☑ Cobble 70 % ☑ Snags 10 % ☐ Undercut Banks 10 % ☑ Sand 5 % ☐ Submerged Macrophytes ___ % ☐ Other (CPOM) 5 % LP
STREAM CHARACTERIZATION	Subsystem Classification ☑ Perennial ☐ Intermittent ☐ Tidal Stream Type ☐ Coldwater ☑ Warmwater

S

Predominant Surrounding Landuse
- ☑ Forest
- ☐ Field/Pasture
- ☐ Agricultural
- ☐ Residential
- ☐ Commercial
- ☑ Industrial
- ☐ Other________

Local Watershed NPS Pollution
- ☐ No evidence
- ☑ Some potential sources
- ☐ Obvious sources

Canopy Cover
- ☑ Partly open
- ☐ Partly-shaded
- ☐ Shaded

High Water Mark 1 m

Local Water Erosion
- ☐ None
- ☑ Moderate
- ☐ Heavy

Estimated Stream Width 6 m

Estimated Stream Depth
- ☐ Riffle .2 m
- ☑ Run .5 m
- ☑ Pool 1.7 m

Velocity 1.3 m/sec 4 ft/50 s

Estimated Reach Length 100 m

Channelized ☐ Yes ☑ No

Dam Present ☐ Yes ☑ No

ION

Indicate the dominant type and record the dominant species present
- ☑ Trees
- ☐ Shrubs
- ☐ Grasses
- ☐ Herbaceous

dominant species present iron wood, sycamore, Hackberry

ON

Indicate the dominant type and record the dominant species present
- ☐ Rooted emergent
- ☐ Rooted submergent
- ☐ Rooted floating
- ☐ Free Floating
- ☐ Floating Algae
- ☐ Attached Algae

dominant species present ________

Portion of the reach with vegetative cover 0 %

SEDIMENT/ SUBSTRATE

Odors
- ☑ Normal
- ☐ Sewage
- ☐ Petroleum
- ☐ Chemical
- ☐ Anaerobic
- ☐ None
- ☐ Other________

Oils
- ☑ Absent
- ☐ Slight
- ☐ Moderate
- ☐ Profuse

Deposits
- ☐ Sludge
- ☐ Sawdust
- ☐ Paper fiber
- ☐ Sand
- ☐ Relict shells
- ☐ Other________

Looking at stones which are not deeply embedded, are the undersides black in color?
- ☑ Yes
- ☐ No

WATER QUALITY

Temperature_____ °C

Specific Conductance_____

Dissolved Oxygen _____

pH _____

Turbidity _____

WQ Instrument Used _____

Water Odors
- ☑ Normal/None
- ☐ Sewage
- ☐ Petroleum
- ☐ Chemical
- ☐ Fishy
- ☐ Other________

Water Surface Oils
- ☐ Slick
- ☐ Sheen
- ☐ Globs
- ☐ Flecks
- ☐ None
- ☐ Other________

Turbidity (if not measured)
- ☑ Clear
- ☐ Slightly turbid
- ☐ Turbid
- ☐ Opaque
- ☐ Water color
- ☐ Other________

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	**Diameter**	**% Composition in Sampling Reach**	**Substrate Type**	**Characteristic**	**% Composition in Sampling Area**
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	100
Boulder	> 256 mm (10")				
Cobble	64-256 mm (2.5"-10")	20	Muck-Mud	black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1"-2.5")	75			
Sand	0.06-2mm (gritty)	5	Marl	grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	< 0.004 mm (slick)				

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

PHYSICAL CHARACTERIZATION

STREAM NAME Grapevine Cr	LOCATION above Clear Fork ~ 700'
STATION # 2 RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY EPA / KY DOW
INVESTIGATORS	
FORM COMPLETED BY Howard	DATE 5/14/02 0845 (AM) PM — REASON FOR SURVEY MTM/VF

SITE LOCATION/MAP

Draw a map of the site and indicate the areas sampled

pix 25, 26, 27

HABITAT TYPES

Indicate the percentage of each habitat type present

☑ Cobble ____% ☐ Snags ____% ☐ Undercut Banks ____% ☐ Sand ____%

☐ Submerged Macrophytes ____% ☐ Other ( ) ____%

STREAM CHARACTERIZATION

Subsystem Classification: ☑ Perennial ☐ Intermittent ☐ Tidal

Stream Type: ☐ Coldwater ☑ Warmwater

* Water too deep & current too swift to conduct RBP.

RIPARIAN ZONE/ INSTREAM FEATURES		
	Predominant Surrounding Landuse ☐ Forest ☐ Commercial ☐ Field/Pasture ☐ Industrial ☐ Agricultural ☐ Other major hwy (29) left bank ☑ Residential **Local Watershed NPS Pollution** ☐ No evidence ☐ Some potential sources ☑ Obvious sources **Canopy Cover** ☑ Partly open ☐ Partly-shaded ☐ Shaded **High Water Mark** 1' ft	**Local Water Erosion** ☐ None ☑ Moderate ☐ Heavy **Estimated Stream Width** 12' ft **Estimated Stream Depth** ☐ Riffle 16" ~~m~~ ☐ Run 1' ft ☐ Pool ____ m **Velocity** 2.5 ~~m/sec~~ ft/sec **Estimated Reach Length** ____ m **Channelized** ☐ Yes ☐ No **Dam Present** ☐ Yes ☐ No
RIPARIAN VEGETATION (18 meter buffer)	**Indicate the dominant type and record the dominant species present** ☑ Trees ☐ Shrubs ☐ Grasses ☐ Herbaceous **dominant species present** ____	
AQUATIC VEGETATION N/A	**Indicate the dominant type and record the dominant species present** ☐ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☐ Free Floating ☐ Floating Algae ☐ Attached Algae **dominant species present** ____ *Portion of the reach with vegetative cover* ____ %	
SEDIMENT/ SUBSTRATE	**Odors** ☑ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other ____ **Oils** ☐ Absent ☐ Slight ☐ Moderate ☐ Profuse	**Deposits** ☐ Sludge ☐ Sawdust ☐ Paper fiber ☑ Sand ☐ Relict shells ☐ Other ____ **Looking at stones which are not deeply embedded, are the undersides black in color?** ☐ Yes ☐ No
WATER QUALITY	**Temperature** 14.73 C **Specific Conductance** 363 **Dissolved Oxygen** 9.12 **pH** 7.75 **Turbidity** ____ **WQ Instrument Used** Hydrolab	**Water Odors** ☑ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other ____ **Water Surface Oils** ☐ Slick ☐ Sheen ☐ Globs ☐ Flecks ☑ None ☐ Other ____ **Turbidity (if not measured)** ☐ Clear ☐ Slightly turbid ☑ Turbid ☐ Opaque ☐ Water color ☐ Other ____

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	**Diameter**	**% Composition in Sampling Reach**	**Substrate Type**	**Characteristic**	**% Composition in Sampling Area**
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	
Boulder	> 256 mm (10")	30			
Cobble	64-256 mm (2.5"-10")	40	Muck-Mud	black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1"-2.5")	10			
Sand	0.06-2mm (gritty)	10	Marl	grey, shell fragments	
Silt	0.004-0.06 mm	10			
Clay	< 0.004 mm (slick)				

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Buffalo Creek	LOCATION off Hwy 1096 just east of Hwy 15 bridge
STATION# 3 RIVERMILE	STREAM CLASS
LAT LONG	RIVER BASIN
STORET #	AGENCY
mands	
FORM COMPLETED BY J. Mandsley	DATE 5/3/00 TIME 1500 AM (PM) REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	(10) 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel **alteration**	Channelization or dredging absent or minimal: stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of **past** channelization, i.e., dredging, (greater than **past 20** yr) may **be** present, bur recent channelization **is** not present.	Channelization may be extensive; embankments or shoring structures **present** on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cemenr: over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 17 16	15 14 (13) 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance beween **riffles** divided by width oirhe stream <7:1 **(generally 5 to 7);** variety of habitat **is** key. In streams whcrc riffles are continuous. placement of boulders or orhcr large. natural **obstruction** is important.	Occurrence of riffles infrequent; distance beween nffles dividcd by the width of the stream is berween 7 to 15.	Occasional riffle or bend: bottom contours provide some habitat; distance between nfflrs divided by the width of	Generally all **flat** water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a
SCORE	20 (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately **stable; infrequent**, small areas of erosion *mostly healed* over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has *areas of erosion; high* erosion potential during **floods.**	Unstable: many eroded areas; **"raw"** areas *frequent along straight* sections and bends: obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left **Bank** (10) 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank (10) 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate **riparian** zone covered **by** native vegetation, including trees, understory **shrubs,** or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident: almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident **bur** nor affecting full plant growth potential to any great extenr: more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; **patches** of bare soil or **closely** cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	(8) 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	(8) 7 6	5 4 3	2 1 0
10. Riparian Vegetative **Zone** Width (score each bank riparian zone)	Width of **riparian** zone >18 meters; **human** activities (i.e., parking lots, **roadbeds,** clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	**Width** of **riparian** zone **6-12 meters**; human activities have impacted zone a great deal.	Width of **riparian** zone <6 meters: little or *no* **riparian** vegetation due **to** human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	3	2 1 **0.**
SCORE ___ (RB)	Right Bank 10 9	8 7 6		

Parameters to be evaluated broader than sampling reach

~ora$core 166

PHYSICAL CHARACTERIZATION

STREAM NAME Buffalo Creek	LOCATION d/s 1096 just east of Hwy 15 bridge
STATION # 3 RIVERMILE	STREAM CLASS
LAT LONG	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS Dorn / Maudsley / Ackerman / RW	
FORM COMPLETED BY J. Maudsley	DATE 5/3/00 TIME 1500 AM (PM) — REASON FOR SURVEY

SITE LOUTIONMAP

Draw a map of the site and indicate the areas sampled

photo 14 (upstream)
photo 15 (downstream)

HABITAT TYPES

Indicate the percentage of each habitat type present

☒ Cobble 90 % ☒ Snags 5 % ☐ Undercut Banks 0 % ☐ Sand 0 %

☐ Submerged Macrophytes ___ % ☐ Other (CPOM) 5 %

STREAM CHARACTERIZATION

Subsystem Classification: ☒ Perennial ☐ Intermittent ☐ Tidal

Stream Type: ☐ Coldwater ☒ Warmwater

322
1.5
6.5
7.5
9.0
10.5 9

RIPARIAN ZONE/ INSTREAM FEATURES	Predominant Surrounding Landuse ☒ Forest ☒ Commercial ☒ Field/Pasture ☒ Industrial ☐ Agricultural ☐ Other____ ☒ Residential Local Watershed NPS Pollution ☐ No evidence ☒ Some potential sources ☒ Obvious sources (road/mining) Canopy Cover ☐ Partly open ☒ Partly shaded ☐ Shaded High Water Mark 1.5 m	Local Water Erosion ☐ None ☒ Moderate ☐ Heavy Estimated Stream Width 4 m Estimated Stream Depth ☐ Riffle .2 m ☐ Run .2 m ☐ Pool .3 m Velocity 1.5 ft/sec m/sec Estimated Reach Length 100 m Channelized ☒ Yes ☐ No Dam Present ☐ Yes ☒ No
RIPARIAN VEGETATION (18 meter buffer)	Indicate the dominant type and record the dominant species present ☐ Trees ☒ Shrubs ☒ Grasses ☐ Herbaceous dominant species present exotics	
AQUATIC VEGETATION	Indicate the dominant type and record the dominant species present ☐ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☐ Free Floating ☐ Floating Algae ☒ Attached Algae dominant species present blue greens / diatoms Portion of the reach with vegetative cover 75 %	
SEDIMENT/ SUBSTRATE	Odors ☒ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other____ Oils ☒ Absent ☐ Slight ☐ Moderate ☐ Profuse	Deposits ☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand ☐ Relict shells ☐ Other none Looking at stones which are not deeply embedded, are the undersides black in color? ☐ Yes ☒ No
WATER QUALITY	Temperature ____ °C Specific Conductance ____ Dissolved Oxygen ____ pH ____ Turbidity ____ WQ Instrument Used ____	Water Odors ☐ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other____ Water Surface Oils ☐ Slick ☐ Sheen ☐ Globs ☐ Flecks ☐ None ☐ Other____ Turbidity (if not measured) ☐ Clear ☐ Slightly turbid ☐ Turbid ☐ Opaque ☐ Water color ☐ Other____

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	100
Boulder	> 256 mm (10")	15			
Cobble	64-256 mm (2.5"-10")	45	Muck-Mud	black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1"-2.5")	40			
Sand	0.06-2mm (gritty)		Marl	grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	< 0.004 mm (slick)				

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Laurel Fork	LOCATION @ Upper Laurel Fork Rd
STATION # 4 RIVERMILE	STREAM CLASS
LAT LONG	RIVER BASIN
STORET #	AGENCY EPA
INVESTIGATORS	
FORM COMPLETED BY Howard Welda	DATE 5/3/00 TIME 0915 (AM) PM / REASON FOR SURVEY KY MTM/VF

Parameters to be evaluated in sampling reach

Habitat Parameter	Optimal	Suboptimal	Marginal	Poor
	Condition Category			
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 (11)	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 (3) 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE				5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 (3) 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	(15) 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE			10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (*score each bank*) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	**Left Bank** 10 9	(8) 7 6	5 4	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 (6)	5 3 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 (9)			
SCORE ___ (RB)	Right **Bank** 10 9	8 7 (6)	5 4 3	2 1 0
***10.* Riparian** Vegetative Zone Width (score each **bank riparian** zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank (10) 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	(8) 7 6	5 4 3	2 1 0

Parameters to be evaluated broader than sampling reach

Total Score *128*

PHYSICAL CHARACTERIZATION

STREAM NAME Laurel Fork	LOCATION @ Upper Laurel Fork Rd.
STATION # RIVERMILE	STREAM CLASS
LAT LONG	RIVER BASIN
STORET #	AGENCY EPA
INVESTIGATORS Howard Weldon	

FORM COMPLETED BY Howard Weldon	DATE 5/3/00 0715 (AM) PM	REASON FOR SURVEY KY MTM/VF

SITE LOCATION/MAP	Draw a map of the site and indicate the areas sampled pix # 14, 15, 16
HABITAT TYPES	Indicate the percentage of each habitat type present ☐ Cobble____% ☐ Snags____% ☐ Undercut Banks____% ☐ Sand____% ☐ Submerged Macrophytes____% ☐ Other ( )____%
STREAM CHARACTERIZATION	Subsystem Classification ☐ Perennial ☐ Intermittent ☐ Tidal Stream Type ☐ Coldwater ☐ Warmwater

RIPARIAN ZONE/ INSTREAM FEATURES	Predominant Surrounding Landuse: ☑ Forest ☐ Commercial ☐ Field/Pasture ☐ Industrial ☐ Agricultural ☐ Other ____ ☐ Residential Local Watershed NPS Pollution: ☐ No evidence ☑ Some potential sources ☐ Obvious sources Canopy Cover: ☐ Partly open ☑ Partly shaded ☐ Shaded High Water Mark 2 ft	Local Water Erosion: ☑ None ☐ Moderate ☐ Heavy Estimated Stream Width 11 ft Estimated Stream Depth: ☐ Riffle 8-10" avg ☐ Run 10" ☐ Pool 1' Velocity 1.67 ft/sec Estimated Reach Length 100 m Channelized ☐ Yes ☑ No Dam Present ☐ Yes ☑ No
RIPARIAN VEGETATION (18 meter buffer)	Indicate the dominant type and record the dominant species present: ☑ Trees ☐ Shrubs ☐ Grasses ☐ Herbaceous dominant species present: beech, ironwood, maples, dogwood	
AQUATIC VEGETATION N/A	Indicate the dominant type and record the dominant species present: ☐ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☐ Free Floating ☐ Floating Algae ☐ Attached Algae dominant species present ____ Portion of the reach with vegetative cover ____ %	
SEDIMENT/ SUBSTRATE	Odors: ☑ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other ____ Oils: ☑ Absent ☐ Slight ☐ Moderate ☐ Profuse	Deposits: ☐ Sludge ☐ Sawdust ☐ Paper fiber ☑ Sand ☐ Relict shells ☑ Other coal fines Looking at stones which are not deeply embedded, are the undersides black in color? ☑ Yes ☐ No
WATER QUALITY	Temperature 13.66 °C Specific Conductance 1550 Dissolved Oxygen 9.54 pH 7.64 Turbidity ____ WQ Instrument Used Hydrolab	Water Odors: ☐ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other ____ Water Surface Oils: ☐ Slick ☐ Sheen ☐ Globs ☐ Flecks ☐ None ☐ Other ____ Turbidity (if not measured): ☐ Clear ☐ Slightly turbid ☐ Turbid ☐ Opaque ☐ Water color ☐ Other ____

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	15
✓ Boulder	> 256 mm (10")	20			
✓ Cobble	64-256 mm (2.5"-10")	40	Muck-Mud	black, very fine organic (FPOM)	10 coal fines
✓ Gravel	2-64 mm (0.1"-2.5")	20			
✓ Sand	0.06-2mm (gritty)	~~20~~ 10	Marl	grey, shell fragments	
Silt	0.004-0.06 mm	10			
Clay	< 0.004 mm (slick)				

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Frugate Fork	LOCATION Frugate Fork Rd
STATION # 5 RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY EPA/KDOW
INVESTIGATORS Howard/Weldon/Call	
FORM COMPLETED BY Howard et al	DATE 5/2/00 TIME 1305 AM (PM) / REASON FOR SURVEY Ky MTM/VF

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and	Gravel, cobble, and	Gravel, cobble, and	Gravel, cobble, and
SCORE				
3. Velocity/Depth Regime	deep, slow-shallow, deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	regimes).		
SCORE	20 19 18 17 16	(15) 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 (6)	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 (12) 11	10 9 8 7 6	5 4 3 2 1 0

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream wirh normal pattern.	Some channelization present. usually in areas oibridge abutments; cvidenca of past channelization, i.e., dredging, (greater rhan past 20 yr) may be present. but recent channelization is not present.	Channelization may bc extensive; embankments or shoring structures present an both banks; and 40 to 80% of stream reach channelized and disrupted.	Ranks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 (18) 17	16/15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Rimes (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width (rhe stream <7:1 generally 5 to 7); ariety of habitat is key. 7 streams where riffles re continuous. lacement of boulders or ther large, natural bstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential or future problems. <5% of bank affected.	Moderately stable: infrequent, small areas of erosion mostly healed over. 5-30% oibank in each has areas of rosion.	Moderately unstable; 30-60% oibank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas irequent along straight sections and bends; obvious bank sloughing: 60-100% of bank has erosional scars.
SCORE ___ (RB)	Left Bank 10 9	8 (7) 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 (9)			
9. Vegetative Prorecrion (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs. or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covcred by native vegetation, but one class of plants is not well-represented; disruption potenrial to any great extent; more rhan one. half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; parches of bare soil or closely cropped potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	
SCORE ___ (RB)	Right Bank 10 (9)			
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Widrh of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts. lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	(2) 1 0
SCORE ___ (RB)	Right Bank 10 9	8 (7) 6	5 4 3	2 1 0

Total Score 138

STREAM NAME Frigate Fork	LOCATION Frigate Fork Rd
STATION # 5 RIVERMILE ____	STREAM CLASS
LAT ____ LONG ____	RIVER BASIN
STORET #	AGENCY EPA / Ky DOW
INVESTIGATORS Howard / Weldon	
FORM COMPLETED BY Howard/Weldon	DATE 5/2/00 1305 AM PM (circled) REASON FOR SURVEY MTM/VF – Ky

SITE LOCATION/MAP

Draw a map of the site and indicate the areas sampled

pix 7, 8

HABITAT TYPES

Indicate the percentage of each habitat type present

☑ Cobble ____% ☑ Snags ____% ☑ Undercut Banks ____% ☐ Sand ____%

☐ Submerged Macrophytes ____% ☑ Other (CPOM) ____%

STREAM CHARACTERIZATION

Subsystem Classification
☑ Perennial ☐ Intermittent ☐ Tidal

Stream Type
☐ Coldwater ☑ Warmwater

RIPARIAN ZONE/ INSTREAM FEATURES	Predominant Surrounding Landuse ☐ Forest ☐ Commercial ☐ Field/Pasture ☐ Industrial ☑ Agricultural ☐ Other road / left bank ☐ Residential → garden / pasture Local Watershed NPS Pollution ☐ No evidence ☑ Some potential sources ☐ Obvious sources Canopy Cover ☑ Partly open ☐ Partly shaded ☐ Shaded High Water Mark 2' ft	Local Water Erosion ☐ None ☑ Moderate ☐ Heavy Estimated Stream Width 8 ft Estimated Stream Depth ☐ Riffle 6-10" ☐ Run 1 ft ☐ Pool 1-2 ft Velocity .77 ft/sec Estimated Reach Length 100 m Channelized ☐ Yes ☑ No Dam Present ☐ Yes ☑ No
RIPARIAN VEGETATION (18 meter buffer)	Indicate the dominant type and record the dominant species present ☑ Trees ☐ Shrubs ☐ Grasses ☐ Herbaceous dominant species present ________	
AQUATIC VEGETATION	Indicate the dominant type and record the dominant species present ☑ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☐ Free Floating ☐ Floating Algae ☐ Attached Algae dominant species present ________ Portion of the reach with vegetative cover ____%	
SEDIMENT/ SUBSTRATE	Odors ☑ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other ________ Oils ☑ Absent ☐ Slight ☐ Moderate ☐ Profuse	Deposits ☐ Sludge ☐ Sawdust ☐ Paper fiber ☑ Sand ☐ Relict shells ☑ Other silt Looking at stones which are not deeply embedded, are the undersides black in color? ☐ Yes ☐ No
WATER QUALITY	Temperature 15 °C Specific Conductance 836 Dissolved Oxygen 9.58 pH 7.19 Turbidity ______ WQ Instrument Used Hydrolab	Water Odors ☑ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other ________ Water Surface Oils ☐ Slick ☐ Sheen ☐ Globs ☐ Flecks ☑ None ☐ Other ________ Turbidity (if not measured) ☑ Clear ☐ Slightly turbid ☐ Turbid ☐ Opaque ☐ Water color ☐ Other ______

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	20
Boulder	> 256 mm (10")	15			
Cobble	64-256 mm (2.5"-10")	45	Muck-Mud	black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1"-2.5")	15			
Sand	0.06-2mm (gritty)	30	Marl	grey, shell fragments	
Silt	0.004-0.06 mm	5			
Clay	< 0.004 mm (slick)				

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Sims Fork	LOCATION @ Sims Fork Rd
STATION # 6 RIVERMILE	STREAM CLASS
LAT LONG	RIVER BASIN
STORET #	AGENCY EPA / KY DOW
INVESTIGATORS	
FORM COMPLETED BY Howard Walden	DATE 5/3/00 TIME 1500 AM PM — REASON FOR SURVEY KY MTM/VF

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available **Cover**	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are ___ new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 (16)	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder **panicles** are 0-*25%* surrounded by fine sediment. Layering of cobble provides diversity of niche **space.**	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, **and** boulder particles are more than **75%** surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 (13) 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	**All** four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the **4** regimes present (if fast-shallow is **missing,** score lower than if missing other regimes).	Only 2 of the **4** habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	(5) 4 3 2 1 0
4. Sediment **Deposition**	Little or **no** enlargement and less than **5%** of the bottom affected by sediment deposition.	Some new increase in from gravel, sand or fine sediment: 5-30% **of** the bottom affected: slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars: 30-50% of the bottom affected; sediment deposits **at** obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; **pools** almost absent **due** to substantial sediment deposition
SCORE	20 19 18 17 16	15 14 13 12 (11)	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 17 (16)	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 (9)	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	(8) 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	(8) 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	(8) 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank (10) 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 (7) 6	5 4 3	2 1 0

Total Score 144

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME Sims Fork	LOCATION @ Sims Fork Rd bridge
STATION # 6 RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY EPA / Ky DOW
INVESTIGATORS Howard/Weldon/Call	
FORM COMPLETED BY Howard / Weldon	DATE ______ AM PM / REASON FOR SURVEY MTM/VF

SITE LOCATION/MAP

Draw a map of the site and indicate the areas sampled

pix 19 – upstream mid pt
pix 20 downstream mid pt

HABITAT TYPES

Indicate the percentage of each habitat type present

☑ Cobble 9 ___% ☐ Snags ___% ☐ Undercut Banks ___% ☑ Sand ___%

☐ Submerged Macrophytes ___% ☐ Other ( ) ___%

STREAM CHARACTERIZATION

Subsystem Classification: ☑ Perennial ☐ Intermittent ☐ Tidal

Stream Type: ☐ Coldwater ☑ Warmwater

:S	**Predominant Surrounding Landuse** ☑ Forest ☐ Commercial ☐ Field/Pasture ☐ Industrial ☐ Agricultural ☒ Other rd along rt bank ☐ Residential **Local Watershed NPS Pollution** ☐ No evidence ☐ Some potential sources ☑ Obvious sources **Canopy Cover** ☐ Partly open ☑ Partly-shaded ☐ Shaded **High Water Mark** 1 ft **Local Water Erosion** ☐ None ☐ Moderate ☑ Heavy *logging opp left bank **Estimated Stream Width** 20 ~~m~~ ft. **Estimated Stream Depth** ☐ Riffle 6-10" ~~m~~ ☐ Run 1' ~~m~~ ☐ Pool ____ m **Velocity** 1.25 m/sec **Estimated Reach Length** 100 m **Channelized** ☐ Yes ☐ No **Dam Present** ☐ Yes ☐ No
RIPARIAN VEGETATION (18 meter buffer)	**Indicate the dominant type and record the dominant species present** ☑ Trees ☐ Shrubs ☐ Grasses ☐ Herbaceous **dominant species present** ____
AQUATIC VEGETATION N/A	**Indicate the dominant type and record the dominant species present** ☐ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☐ Free Floating ☐ Floating Algae ☐ Attached Algae **dominant species present** ____ **Portion of the reach with vegetative cover** ____ %
SEDIMENT/ SUBSTRATE	**Odors** ☑ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other ____ **Oils** ☐ Absent ☐ Slight ☐ Moderate ☐ Profuse **Deposits** ☐ Sludge ☐ Sawdust ☐ Paper fiber ☑ Sand ☐ Relict shells ☐ Other ____ **Looking at stones which are not deeply embedded, are the undersides black in color?** ☐ Yes ☑ No
WATER QUALITY	**Temperature** 18.57 °C **Specific Conductance** 420 **Dissolved Oxygen** 9.52 **pH** 8.14 **Turbidity** ____ **WQ Instrument Used** Hydrolab **Water Odors** ☑ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other ____ **Water Surface Oils** ☐ Slick ☐ Sheen ☐ Globs ☐ Flecks ☑ None ☐ Other ____ **Turbidity (if not measured)** ☐ Clear ☐ Slightly turbid ☑ Turbid ☐ Opaque ☐ Water color ☐ Other ____

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	**Diameter**	**% Composition in Sampling Reach**	**Substrate Type**	**Characteristic**	**% Composition in Sampling Area**
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	<10
✓ Boulder	> 256 mm (10")	30			
✓ Cobble	64-256 mm (2.5"-10")	30	Muck-Mud	black, very fine organic (FPOM)	
✓ Gravel	2-64 mm (0.1"-2.5")	15			
✓ Sand	0.06-2mm (gritty)	15	Marl	grey, shell fragments	
Silt	0.004-0.06 mm	10			
Clay	< 0.004 mm (slick)				

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Spring Fk / Quicksand	LOCATION nr confluence with Hughes Ck
STATION # 7 RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY EPA / KY DOW
INVESTIGATORS Howard / Welker / Call	
FORM COMPLETED BY Howard Welker	DATE 5/2/00 TIME 1000 (AM) PM — REASON FOR SURVEY MTM/VF

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover: mix of snag. submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations: presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking
SCORE	20 19 18 17 16	15 14/19 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 (13) 12 (11)	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slowdeep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 (9) 8 7 6	5 4 3 2 1 0
4. Sediment **Deposition**	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected: sediment deposits at obstructions, constrictions, and bends: moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development: more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 (8) 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel: or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 3 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 (7) 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 (9)	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 7 (6)	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	(8) 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	(2) 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	(5) 4 3	2 1 0

Total Score 131

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME Spring Fk/Quicksand	LOCATION @ Confl. with Hughes Ck
STATION # 7 RIVERMILE ____	STREAM CLASS
LAT ____ LONG ____	RIVER BASIN
STORET #	AGENCY EPA /KYDOW
INVESTIGATORS Howard/Weldon/Call	
FORM COMPLETED BY Howard/Weldon	DATE 5/2/00 1000 AM PM — REASON FOR SURVEY MTM/VF

SITE LOCATION/MAP	Draw a map of the site and indicate the areas sampled pix 2,3
HABITAT TYPES	Indicate the percentage of each habitat type present ☐ Cobble____% ☐ Snags____% ☐ Undercut Banks____% ☐ Sand____% ☐ Submerged Macrophytes____% ☐ Other ( )____%
STREAM CHARACTERIZATION	Subsystem Classification ☒ Perennial ☐ Intermittent ☐ Tidal Stream Type ☐ Coldwater ☒ Warmwater

a5

RIPARIAN ZONE/ INSTREAM FEATURES	**Predominant Surrounding Landuse** ☐ Forest ☐ Commercial ☐ Field/Pasture ☐ Industrial ☐ Agricultural ☐ Other road/RR either side ☐ Residential **Local Watershed NPS Pollution** ☐ No evidence ☐ Some potential sources ☑ Obvious sources **Canopy Cover** ☑ Partly open ☐ Partly-shaded ☐ Shaded **High Water Mark** <1 m **Local Water Erosion** ☐ None ☑ Moderate ☐ Heavy **Estimated Stream Width** 15 ft **Estimated Stream Depth** ☐ Riffle 0.5 ft ☐ Run 1 ft ☐ Pool ____ m **Velocity** 2.5 ft/sec **Estimated Reach Length** 100 m **Channelized** ☐ Yes ☑ No **Dam Present** ☐ Yes ☑ No
RIPARIAN VEGETATION (18 meter buffer)	**Indicate the dominant type and record the dominant species present** ☑ Trees ☐ Shrubs ☐ Grasses ☐ Herbaceous **dominant species present** ____
AQUATIC VEGETATION	**Indicate the dominant type and record the dominant species present** ☐ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☐ Free Floating ☐ Floating Algae ☐ Attached Algae **dominant species present** ____ **Portion of the reach with vegetative cover** ____ %
SEDIMENT/ SUBSTRATE	**Odors** ☑ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other ____ **Oils** ☑ Absent ☐ Slight ☐ Moderate ☐ Profuse **Deposits** ☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand ☐ Relict shells ☐ Other ____ ***Looking at stones which are not deeply embedded, are the undersides black in color?*** ☑ Yes ☐ No
WATER QUALITY	**Temperature** 15.01 °C **Specific Conductance** 480 **Dissolved Oxygen** 9.17 **pH** 7.15 **Turbidity** ____ **WQ Instrument Used** Hydrolab **Water Odors** ☑ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other ____ **Water Surface Oils** ☐ Slick ☐ Sheen ☐ Globs ☐ Flecks ☑ None ☐ Other ____ **Turbidity (if not measured)** ☐ Clear ☑ Slightly turbid ☐ Turbid ☐ Opaque ☐ Water color ☐ Other ____

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	**Diameter**	***% Composition in Sampling Reach***	**Substrate Type**	**Characteristic**	**% Composition in Sampling Area**
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	10
Boulder	> 256 mm (10")				
Cobble	64-256 mm (2.5"-10")	50	Muck-Mud	black, very fine organic (FPOM) (coal fine)	10
Gravel	2-64 mm (0.1"-2.5")	10			
Sand	0.06-2mm (gritty)	30	Marl	grey, shell fragments	
Silt	0.004-0.06 mm	10			
Clay	< 0.004 mm (slick)				

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

STREAM NAME Lost creek	LOCATION @ 1446
STATION # 9 RIVERMILE	STREAM CLASS
LAT LONG	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS LD JM, JA, SW	
FORM COMPLETED BY LD	DATE 5-2-00 TIME 1530 AM (PM) — REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 17	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine Sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE 15	20 19 18 17 16	(15) 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 14	20 19 18 17 16	15 (14) 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 18	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream wirh normal pattern.	Some channelization present, usually in areas of bridge abutments; evidcncc of past channelization, i.e., dredging, (greater than pasr 20 yr) may be prcscnr, but recent channelization is nor present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent: ratio of distance between riffles divided by width the stream <7:1 generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent: distance between riffles divided by the widrh of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; disrance between riffles divided by the widrh of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; disrance between riffles divided by the width of the stream is a ratio of >25.
SCORE 18	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable: 30-60% of bank in reach has areas of erosion: high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends: obvious bank sloughing: 60-100% of bank has
SCORE 8 (LB)	Left Bank 10 9	(8) 7 6	5 4 3	2 1 0
SCORE 10 (RB)	Right Bank (10)			
9. Vegetative Protection (score each bank)	More than 90% of rhe streambank surfaces and immediate riparian zone covered by native vegetation, including trees. understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or nor evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potcnrial to any great extent; more rhan one-half of the potential plant stubble hcighr remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; parches uibare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of rhr streambank surfaces covered by vegetation; disruption of streambank vegetation is very high: vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 9 (LB)	Left Bank 10 9	8 7 6	5 3 3	2 1 0
SCORE 10 (RB)	Right Bank 10) 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds. clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Widrh of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human acrivities.
SCORE 10 (LB)	Left Bank 10. 9	8 7 6.	5 4 3	2 1 0
SCORE 6 (RB)	Right Bank 10 9	8 7 (6)	5	

Total Score 171

STREAM NAME Lost Creek		LOCATION @ 1446	
STATION4 9	RIVERMILE	STREAM CLASS	
LAT	LONG	RIVER BASIN	
STORET #		AGENCY	
INVESTIGATORS W, JM, OA, SW			
FORM COMPLETED BY WA		DATE 5-2-00 AM (PM)	REASON FOR SURVEY

SITE LOCATION/MAP	-aw a map of the site and indicate the areas sampled photo #5 down photo #6 up
HABITAT TYPES	Indicate the percentage of each habitat type present ☑ Cobble 45 % ☑ Snags 15 % ☑ Undercut Banks 10 % ☑ Sand 20 % ☐ Submerged Macrophytes ___ % ☐ Other (CPOM) 10 %
STREAM CHARACTERIZATION	Subsystem Classification ☑ Perennial ☐ Intermittent ☐ Tidal Stream Type ☐ Coldwater ☑ Warmwater

RIPARIAN ZONE/ INSTREAM FEATURES		
	Predominant Surrounding Landuse ☑ Forest ☐ Commercial ☐ Field/Pasture ☑ Industrial ☐ Agricultural ☐ Other ____ ☑ Residential **Local Watershed NPS Pollution** ☐ No evidence ☐ Some potential sources ☑ Obvious sources **Canopy Cover** ☑ Partly open ☐ Partly shaded ☐ Shaded **High Water Mark** 2 m	**Local Water Erosion** ☐ None ☐ Moderate ☑ Heavy **Estimated Stream Width** 7 m **Estimated Stream Depth** ☑ Riffle .2 m ☑ Run .5 m ☑ Pool .7 m **Velocity** 1.3 ft/sec m/sec **Estimated Reach Length** 100 m **Channelized** ☐ Yes ☑ No **Dam Present** ☐ Yes ☑ No
RIPARIAN VEGETATION (18 meter buffer)	**Indicate the dominant type and record the dominant species present** ☐ Trees ☑ Shrubs ☐ Grasses ☑ Herbaceous **dominant species present** ragweed, ironweed, sycamore, magnolia	
AQUATIC VEGETATION	**Indicate the dominant type and record the dominant species present** ☐ Rooted emergent ☑ Rooted submergent ☐ Rooted floating ☐ Free Floating ☐ Floating Algae ☑ Attached Algae **dominant species present** ____ **Portion of the reach with vegetative cover** 70%	
SEDIMENT/ SUBSTRATE	**Odors** ☑ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other ____ **Oils** ☑ Absent ☐ Slight ☐ Moderate ☐ Profuse	**Deposits** ☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand ☐ Relict shells ☐ Other ____ **Looking at stones which are not deeply embedded, are the undersides black in color?** ☐ Yes ☑ No
WATER QUALITY	**Temperature** ____ °C **Specific Conductance** ____ **Dissolved Oxygen** ____ **pH** ____ **Turbidity** ____ **WQ Instrument Used** ____	**Water Odors** ☑ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other ____ **Water Surface Oils** ☐ Slick ☐ Sheen ☐ Globs ☐ Flecks ☑ None ☐ Other ____ **Turbidity (if not measured)** ☑ Clear ☐ Slightly turbid ☐ Turbid ☐ Opaque ☐ Water color ☐ Other ____

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	**Diameter**	**% Composition in Sampling Reach**	**Substrate Type**	**Characteristic**	**% Composition in Sampling Area**
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	100
Boulder	> 256 mm (10")				
Cobble	64-256 mm (2.5"-10")	10	Muck-Mud	black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1"-2.5")	75			
Sand	0.06-2mm (gritty)	15	Marl	grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	< 0.004 mm (slick)				

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAMNAME Clemons Fork	LOCATION
STATION# 10 RIVERMILE	STREAM CLASS
LAT ____ LONG ____	RIVER BASIN
STORET#	AGENCY EPA / KyDOW
INVESTIGATORS	
FORM COMPLETED BY Howard Weldon	DATE 5/2/00 TIME 1500 AM PM — REASON FOR SURVEY MTM/VF

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	(15) 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends moderate deposition of	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	(15) 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 (16)	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated in an area broader than sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement: over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

Total Score 147

STREAM NAME Clemons Fork	LOCATION in Robinson Forest
STATION # 10 RIVERMILE ____	STREAM CLASS
LAT ____ LONG ____	RIVER BASIN
STORET #	AGENCY EPA / KyDOW
INVESTIGATORS [illegible] / Welden / [illegible]	
FORM COMPLETED BY Howard / Welden	DATE 5/2/00 15:00 AM (PM) REASON FOR SURVEY MTM / VF

TE LOCATION/MAP

Draw a map of the site and indicate the areas sampled

Pix 11, 12, 13

HABITAT TYPES

Indicate the percentage of each habitat type present

☑ Cobble ____% ☑ Snags ____% ☑ Undercut Banks ____% ☐ Sand ____%

☐ Submerged Macrophytes ____% ☑ Other (leaf packs) ____%

STREAM

Subsystem Classification ☑ Perennial ☐ Intermittent ☐ Tidal

Stream Type ☐ Coldwater ☑ Warmwater

5

Predominant Surrounding Landuse
☑ Forest ☐ Commercial
☐ Field/Pasture ☐ Industrial
☐ Agricultural ☐ Other________
☐ Residential

Local Watershed NPS Pollution
☑ No evidence ☐ Some potential sources
☐ Obvious sources

Canopy Cover
☐ Partly open ☐ Partly-shaded ☑ Shaded

High Water Mark 1.5 ft

Local Water Erosion
☑ None ☐ Moderate ☐ Heavy

Estimated Stream Width 15-18 ft

Estimated Stream Depth
☑ Riffle 10"/ ft ☐ Run 1 ft
☐ Pool 2-3 ft

Velocity 1.25 ft/sec

Estimated Reach Length 100 m.

Channelized ☐ Yes ☑ No

Dam Present ☐ Yes ☑ No

RIPARIAN VEGETATION (18 meter buffer)

Indicate the dominant type and record the dominant species present
☑ Trees ☐ Shrubs ☐ Grasses ☐ Herbaceous

dominant species present ________

AQUATIC VEGETATION

N/A

Indicate the dominant type and record the dominant species present
☐ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☐ Free Floating
☐ Floating Algae ☐ Attached Algae

dominant species present ________

Portion of the reach with vegetative cover ____%

SEDIMENT/ SUBSTRATE

Odors
☑ Normal ☐ Sewage ☐ Petroleum
☐ Chemical ☐ Anaerobic ☑ None
☐ Other________

Oils
☑ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits
☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand
☐ Relict shells ☐ Other________

Looking at stones which are not deeply embedded, are the undersides black in color?
☐ Yes ☑ No

WATER QUALITY

Temperature 15.4 °C

Specific Conductance 65.8

Dissolved Oxygen 9.50

pH 7.08

Turbidity ________

WQ Instrument Used Hydrolab

Water Odors
☑ Normal/None ☐ Sewage
☐ Petroleum ☐ Chemical
☐ Fishy ☐ Other________

Water Surface Oils
☐ Slick ☐ Sheen ☐ Globs ☐ Flecks
☑ None ☐ Other________

Turbidity (if not measured)
☑ Clear ☐ Slightly turbid ☐ Turbid
☐ Opaque ☐ Water color ☐ Other________

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)

Substrate Type	Diameter	% Composition in Sampling Reach
Bedrock		
Boulder	> 256 mm (10")	30
Cobble	64-256 mm (2.5"-10")	40
Gravel	2-64 mm (0.1"-2.5")	20
Sand	0.06-2mm (gritty)	10
Silt	0.004-0.06 mm	
Clay	< 0.004 mm (slick)	

ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)

Substrate Type	Characteristic	% Composition in Sampling Area
Detritus	sticks, wood, coarse plant materials (CPOM)	15
Muck-Mud	black, very fine organic (FPOM)	
Marl	grey, shell fragments	

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Coles Fork	LOCATION @ Buckhorn Cl. Rd
STATION # 11-R RIVERMILE	STREAM CLASS
LAT LONG	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS LD JM, JA, SW	
FORM COMPLETED BY LD	DATE 5-2-00 TIME AM PM · REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. **Epifaunal** Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less rhan desirable; substrate frequently disturbed or removed	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 17	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel. cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel. cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE 18	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE 16	20 19 18 17 (16)	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	and less than 5% of the bottom aifcctcd by sediment deposition.	from gravel, sand or line sedimcnr: 5-30% of the bottom affected; slight deposition in pools.	sediment on old and new bars: 30-50% ofrhe bottom affected; sediment deposits at obsrmctions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development: more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 15 / SCORE 15	20 19 18 17 16	(15) 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow **Status**	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% ofthe available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 17	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

rameters to be evaluated b ler than sampling reach

Aabimt Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream wirh normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of **past** channelization, i.e., dredging, (greater than past **20** yrj **may** be present. but recent channelization is nor presenr.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over **80% of the stream reach** channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 20	(20) 19 18 17 16	15 14 13 12 11	0 9 s 7 6	5 4 3 2 1 0
7. Frequency of Riffles **(or** bends)	relatively frequent; ratio f distance between ffles divided by width i the stream <7:1 generally 5 to 7); variety of habitat **is** key. In streams where riffles are connnuous, placement of boulders or other large, natural obstruction is important.	ıfrequent; distance etween **riiflcs** divided y the widrh of the tream **is** between *1* to **5**.	)ccasional riffle or end; bottom contours rovide some habitat; istance berween rifles ivided by the widrh of ne stream is between 15) 25.	Generally **all** flat water or shallow riifles; poor habitat; distance between riffles divided by the width of the stream **is** a ratio of >25.
SCORE 19	20 (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each **bank**) Note: determine left or right **side** by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; nfrequent, small areas of :rosion mostly healed ɔver. 5-30% oibank in each has areas o i :rosion.	Moderately unstable; 30-60% oibank in reach **has** ıreas of erosion; high rosion potential during loods.	Jnstable; many eroded ıreas; "raw" areas requent along straight ections and bends: obvious bank sloughing; 60-100% oibank **has** :rosional scars.
SCORE 8 (LB)	Left Bank 10 9	(8) 7 6	5 4 3	2 1 0
SCORE 8 (RB)	Right Bank 10 9	(8) 7		
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian **zone** covered **by** native vegetation, including trees, understory **shrubs**, **or** nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost **all** plants allowed to grow naturally.	70-90% of the streambank surfaces covered **by** native vegetation, but one class of plants is not **well-**represenred: **disruption** evident **bur** nor affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; parches of bare soil or **closely** cropped vegetation common: less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 9 (LB)	Left Bank 10 (9)	a 7 6	5 4 3	2. 1 0
SCORE 9 (RB)	Right Bank 10 (9)			
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-11 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE 10 (LB)	Left Bank (10) 9	8 1 6	5 4 3	2 I 0.
SCORE 8 (RB)	Right Bank 10 9	(8) 7		

Total Score 174

STREAM NAME		LOCATION	@ Buckhorn Cc. Rd.
STATION # 11-R	RIVERMILE	STREAM CLASS	
LAT	LONG	RIVER BASIN	
STORET #		AGMCY	
INVESTIGATORS LD JM JA SL			
FORM COMPLETED BY		DATE 5-2-00 / AM PM	REASON FOR SURVEY

TE LOCATION/MAP	raw a map of the site and indicate the areas sampled Photo # 1 upstream Photo # 2 downstream
HABITAT TYPES	Indicate the percentage of each habitat type present ☐ Cobble 40 % ☐ Snags 15 % ☐ Undercut Banks 10 % ☐ Sand 30 % ☐ Submerged Macrophytes 0 % ☐ Other (CPOm) 5 %
STREAM CHARACTERIZATION	Subsystem Classification ☐ Perennial ☐ Intermittent ☐ Tidal Stream Type ☐ Coldwater ☐ Warmwater

RIPARIAN ZONE/ INSTREAM FEATURES	**Predominant Surrounding Landuse** ☑ Forest ☐ Commercial ☐ Field/Pasture ☐ Industrial ☐ Agricultural ☐ Other ______ ☐ Residential **Local Watershed NPS Pollution** ☐ No evidence ☑ Some potential sources ☐ Obvious sources **Canopy Cover** ☐ Partly open ☑ Partly-shaded ☐ Shaded **High Water Mark** 1 m	**Local Water Erosion** ☐ None ☑ Moderate ☐ Heavy **Estimated Stream Width** 9 m **Estimated Stream Depth** ☑ Riffle .2 m ☑ Run .5 m ☑ Pool .7 m **Velocity** 1 ft/sec m/sec **Estimated Reach Length** 100 m **Channelized** ☐ Yes ☑ No **Dam Present** ☐ Yes ☑ No
RIPARIAN VEGETATION (18 meter buffer)	**Indicate the dominant type and record the dominant species present** ☑ Trees ☑ Shrubs ☐ Grasses ☐ Herbaceous **dominant species present** May Apple, Hemlock, Beech, Cherry, Poplar, Sycamore	
AQUATIC VEGETATION	**Indicate the dominant type and record the dominant species present** ☑ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☐ Free Floating ☐ Floating Algae ☐ Attached Algae **dominant species present** grass **Portion of the reach with vegetative cover** 3 %	
SEDIMENT/ SUBSTRATE	**Odors** ☑ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other ______ **Oils** ☑ Absent ☐ Slight ☐ Moderate ☐ Profuse	**Deposits** ☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand ☐ Relict shells ☐ Other ______ **Looking at stones which are not deeply embedded, are the undersides black in color?** ☐ Yes ☑ No
WATER QUALITY	**Temperature** ______ °C **Specific Conductance** ______ **Dissolved Oxygen** ______ **pH** ______ **Turbidity** ______ **WQ Instrument Used** ______	**Water Odors** ☑ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other ______ **Water Surface Oils** ☐ Slick ☐ Sheen ☐ Globs ☐ Flecks ☑ None ☐ Other ______ **Turbidity (if not measured)** ☑ Clear ☐ Slightly turbid ☐ Turbid ☐ Opaque ☐ Water color ☐ Other ______

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	**Diameter**	**% Composition in Sampling Reach**	**Substrate Type**	**Characteristic**	**% Composition in Sampling Area**
Bedrock		50	Detritus	sticks, wood, coarse plant materials (CPOM)	100
Boulder	> 256 mm (10")				
Cobble	64-256 mm (2.5"-10")	25	Muck-Mud	black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2mm (gritty)	25	Marl	grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	< 0.004 mm (slick)				

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

STREAMNAME Double	LOCATION @ 1501
STATION # 12-R RIVERMILE	STREAM CLASS
LAT LONG	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS LD, JM, JA, RW	
FORM COMPLETED BY LD	DATE 5-3-00 TIME 1345 AM PM ✓ — REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0- [illegible] sediment. Layering of cobble provides diversity of niche space.	[illegible] boulder particles are 25 [illegible] sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	(15) 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
Channel Iteration	Channelization or dredging absent or minimal; stream wirh normal pattern.	Some channelization presenr, usually in areas of bridge abutments; evidence of past channelization, i.e., drodging, (greater than past 20 yr) may be present, bur recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks: and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement: over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
CORE	:0 (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
. Frequency of iiffles (or bends)	)ccurrence of riffles elatively frequent; ratio if distance between iffles divided by width if the stream C7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous. placement of bouiders or other large, natural obstruction is important.	Occurrence of riffles infrequenr; distance berween riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend: bottom contours provide some habitat: distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
;CORE	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
I. Bank Stability score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly-healed over. 5-30% oibank in reach has areas of erosion.	Moderately unstable: 30-60% ofbank in reach has areas ot'crosion: high erosion potential during floods.	Unstable: many eroded areas; "raw" areas irequenr along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 (9)	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 (9)	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 9046 of the streambank surfaces and immediate riparian zone covered by native vegetation. including trees, understory shrubs. or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not cvidcnt: almost all plants allowed to grow naturally.	70-90% of the streambank sunaccs covered by native vegetation, bur one class of plants is nor well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.-	50-70% of the streambank surfaces covered by vegetation; disruption obviou::: parches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation: disruption of streambank vegetation is very high: vegetation has been rcmovrd to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 (9)	8 7 6	5 4 3	3. 1 0
SCORE ___ (RB)	Right Bank 10			
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 merers: human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human acrivities have impacted zone only minimally.	Width of riparian zone 6-12 merers: human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank (10) (9)	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank (10) 9	8 7 6	5 4 3	2 1 0

Total Score IS\

STREAM NAME Big Double	LOCATION @ 1501
STATION # 12-R RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS LD JM JA RW	
FORM COMPLETED BY LD	DATE 5-3-00 AM (PM) | REASON FOR SURVEY

SITE LOCATION/MAP

aw a map of the site and indicate the areas sampled

photo # 12 up
photo # 13 down

HABITAT TYPES

Indicate the percentage of each habitat type present

☑ Cobble 70 % ☑ Snags 15 % ☑ Undercut Banks 5 % ☑ Sand 5 %

☐ Submerged Macrophytes ____ % ☐ Other (CPOM) 5 %

STREAM CHARACTERIZATION

Subsystem Classification
☑ Perennial ☐ Intermittent ☐ Tidal

Stream Type
☐ Coldwater ☑ Warmwater

PARIAN ZONE/ STREAM FEATURES	edominant Surrounding Landuse Forest ☐ Commercial Field/Pasture ☐ Industrial Agricultural ☐ Other ____ Residential ocal Watershed NPS Pollution No evidence ☑ Some potential sources Obvious sources anopy Cover Partly open ☐ Partly-shaded ☐ Shaded ligh Water Mark 1.5 m	Local Water Erosion ☐ None ☑ Moderate ☐ Heavy Estimated Stream Width 7 m Estimated Stream Depth ☐ Riffle .2 m ☐ Run .5 m ☐ Pool 1 m Velocity 1.2 ft/sec m/sec Estimated Reach Length 100 m Channelized ☐ Yes ☑ No Dam Present ☐ Yes ☑ No
IPARIAN VEGETATION (8 meter buffer)	Indicate the dominant type and record the dominant species present ☑ Trees ☐ Shrubs ☐ Grasses ☐ Herbaceous dominant species present Birch, Sycamore	
AQUATIC VEGETATION	Indicate the dominant type and record the dominant species present ☐ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☐ Free Floating ☐ Floating Algae ☑ Attached Algae dominant species present ____ Portion of the reach with vegetative cover 5 %	
S________TE	Odors ☑ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other ____ Oils ☑ Absent ☐ Slight ☐ Moderate ☐ Profuse	Deposits ☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand ☐ Relict shells ☐ Other ____ Looking at stones which are not deeply embedded, are the undersides black in color? ☐ Yes ☑ No
WATER QUALITY	Temperature ____ °C Specific Conductance ____ Dissolved Oxygen ____ pH ____ Turbidity ____ WQ Instrument Used ____	Water Odors ☑ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other ____ Water Surface Oils ☐ Slick ☐ Sheen ☐ Globs ☐ Flecks ☑ None ☐ Other ____ Turbidity (if not measured) ☑ Clear ☐ Slightly turbid ☐ Turbid ☐ Opaque ☐ Water color ☐ Other ____

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	100
Boulder	> 256 mm (10")	5			
Cobble	64-256 mm (2.5"-10")	50	Muck-Mud	black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1"-2.5")	40			
Sand	0.06-2mm (gritty)	5	Marl	grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	< 0.004 mm (slick)				

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

STREAM NAME Sugar Cr	LOCATION @ Redbird
STATION # 13-R RIVERMILE	STREAM CLASS
LAT LONG	RIVER BASM
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY	DATE 5-3-00 TIME 1100 AM PM / REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	2010% mix of stable habitat; habitat availability less thin desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 19	20 (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE 18	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slaw-shallow arc missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
SCORE 17	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or tine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends: moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% o i the bottom chmgingfrequenrly: pools almost absent due to substantial sediment deposition.
SCORE 15	20 19 18 17 16	(15) 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 17	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration 19	Channelization or dredging absent or minimal; stream wirh normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be presenr. bur recent channelization is not present.	Channelization may bc extensive; embankments or shoring structures present on both banks: and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement: over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed enrirely.
SCORE	20 (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent: ratio of distance beween **riffles** divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. in streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequenr: distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend: bottom contours provide some habitat; distance between riffles dividcd by the width of the stream is between 15 to 25.	Generally ail flat water or shallow riffles; poor habitat; distance between riffles dividcd by the width o i the stream is a ratio of >25.
SCORE 19	20 (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	**Bank** stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas o i erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 7 (LB)	Left Bank 10 (9)	8 7 6	5 4 3	2 1 0
SCORE 9 (RB)	Right Bank 10 (9)	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimai or nor evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation. bur one class of plants is nor well-represented; disruption evident but not affecting full plant growth potential to any great extenr: more than one-half of rhc potential plant stubble height remaining.	50-70% oithc streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vcgctation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation: disruption of streambank vegetation is vey high: vegetation has been removed to 5 centimeters or less in average stubble hcighr.
SCORE __ (LB)	Left Bank (10) 9	a 7 6	5 a 3	2 1 0
SCORE 10 (RB)	Right Bank (10) 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zonc)	Width of riparian zone >18 meters; human activities (i.e., **parking** lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters: human activities have impacted zone Only minimally.	Width of riparian zone 6-12 meters; human activities have impacred zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE 19 (LB)	Left Bank (10) 9	8 7 6	5 4. 3	2 1 0
SCORE 9 (RB)	Right Bank 10 (9)	8 7 6	5 4 3	2 1 0

Total Score 181

STREAM NAME Sugar Cr	LOCATION @ Red Bird	
STATION # 13-R RIVERMILE ____	STREAM CLASS	
LAT ____ LONG ____	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS LD, JA, JM, RW		
FORM COMPLETED BY LD	DATE 5-3-00 (AM) PM	REASON FOR SURVEY

SITE LOCATION/MAP	Draw a map of the site and indicate the areas sampled photo #7 down photo #8 up
HABITAT TYPES	Indicate the percentage of each habitat type present ☑ Cobble 65 % ☑ Snags 5 % ☑ Undercut Banks 10 % ☑ Sand 5 % ☐ Submerged Macrophytes ____ % ☐ Other (CPOM) 15 %
STREAM CHARACTERIZATION	Subsystem Classification ☑ Perennial ☐ Intermittent ☐ Tidal Stream Type ☐ Coldwater ☑ Warmwater

RIPARIAN ZONE/ INSTREAM FEATURES	
	Predominant Surrounding Landuse ☑ Forest ☐ Commercial ☐ Field/Pasture ☑ Industrial ☐ Agricultural ☐ Other ☐ Residential **Local Watershed NPS Pollution** ☐ No evidence ☑ Some potential sources ☐ Obvious sources **Canopy Cover** ☑ Partly open ☐ Partly-shaded ☐ Shaded **High Water Mark** 1 m **Local Water Erosion** ☐ None ☑ Moderate ☐ Heavy **Estimated Stream Width** 6 m **Estimated Stream Depth** ☐ Riffle .2 m ☐ Run .5 m ☐ Pool .75 m **Velocity** 1.2 ft/sec m/sec **Estimated Reach Length** 100 m **Channelized** ☐ Yes ☑ No **Dam Present** ☐ Yes ☑ No
RIPARIAN VEGETATION (18 meter buffer)	**Indicate the dominant type and record the dominant species present** ☑ Trees ☐ Shrubs ☐ Grasses ☐ Herbaceous **dominant species present** Hemlock, sycamore, ironwood, magnolia
AQUATIC VEGETATION	**Indicate the dominant type and record the dominant species present** ☐ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☐ Free Floating ☐ Floating Algae ☑ Attached Algae **dominant species present** **Portion of the reach with vegetative cover** 5 %
SEDIMENT/ SUBSTRATE	**Odors** ☑ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other **Oils** ☑ Absent ☐ Slight ☐ Moderate ☐ Profuse **Deposits** ☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand ☐ Relict shells ☐ Other **Looking at stones which are not deeply embedded, are the undersides black in color?** ☐ Yes ☑ No
WATER QUALITY	**Temperature** ___ °C **Specific Conductance** ___ **Dissolved Oxygen** ___ **pH** ___ **Turbidity** ___ **WQ Instrument Used** ___ **Water Odors** ☑ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other **Water Surface Oils** ☐ Slick ☐ Sheen ☐ Globs ☐ Flecks ☑ None ☐ Other **Turbidity (if not measured)** ☑ Clear ☐ Slightly turbid ☐ Turbid ☐ Opaque ☐ Water color ☐ Other

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	100
Boulder	> 256 mm (10")	10			
Cobble	64-256 mm (2.5"-10")	50	Muck-Mud	black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1"-2.5")	25			
Sand	0.06-2mm (gritty)	5	Marl	grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	< 0.004 mm (slick)				

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

STREAM NAME Sugar Cr	LOCATION @ Redbird
STATION # 13-R-Dup RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover: mix of snags. submerged logs. undercut banks. cobblc or other stable habitat nnd at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat: well-suited for full colonization potential; adequate habitat for maintenance oipopuiations: presence of additional substrate in the form of newfall, but nor yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate irequenrly disturbed or removed.	Less than 20% stabie habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 19	20 (19) IS. '17 16	15 14 13 12 11	10 9 8 7 6	5 4 . 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provider diversity of niche space.	Gravel, cobble, md boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble. and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble. and boulder panicles are more than 75% surrounded by fine sediment.
SCORE 19	20 19) 18 17 16	15 14 13 12 11	10 9 8 T 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present ;if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE 16	20 19 18 ~~17~~ (16)	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sedimenr; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or tine sediment on old nnd new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends: moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frcquenrly: pools almost absent due to substantial sediment deposinon
SCORE 15	20 19 18 17 16	(15) 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills>75% ofthe available channel; or <25% of channel substrare is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates arc mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 18	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
.Channel .lteration	Channelization or dredging absent or minimal: stream with normal pattern.	Sume channelization present. usually in areas of bridge abutments; evidence of past channelizsiun, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is nor present.	Channelization may be extensive; embankments or shoring structures present on both banks: and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement: aver 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 19	20 (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width oj the stream c7:l (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous. placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riiflcs divided by the width of the stream is between 1 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width o i the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE 19	20. (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks suble: avidenct oferosion or tank failure absent or minimal; little porenrial for future problems. cS% ofbank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 9 (LB)	Left Bank 10 (9)	8 7 6	5 4 3	2 1 0
SCORE 9 (RB)	Right Bank 10 (9)	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of rhe streambank surfaces covered by native vegetation, bur one class of plants is not well-represenred: disruption evident bur nor affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble hcighr remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious: patches oibarc soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption o istreambank vegetation is very high: vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 10 (LB)	Left Bank (10) 9	8 7 6	5 4 3	2. 1 0
SCORE 10 (RB)	Right Bank (10) 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE 8 (LB)	Left Bank 10 9	(8) 7 6	5 4 3	2 1 0
SCORE 8 (RB)	Right Bank 10 9	(8) 7 6	5 4 3	2 1 0

Total Score 179

STREAM NAME Sugar Cr	LOCATION @ Redbird
STATION # 13-Rdup RIVERMILE ____	STREAM CLASS
LAT ____ LONG ____	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS W, JM, JA, W	
FORM COMPLETED BY W	DATE 5-3-00 AM PM — REASON FOR SURVEY

TE LOCATION/MAP

raw a map of the site and indicate the areas sampled

photo # 10 up
photo # 11 down

HABITAT TYPES

Indicate the percentage of each habitat type present

☑ Cobble 80 % ☑ Snags 5 % ☑ Undercut Banks 5 % ☑ Sand 5 %
☐ Submerged Macrophytes ____ % ☐ Other (CPOM) 5 %

STREAM CHARACTERIZATION

Subsystem Classification
☑ Perennial ☐ Intermittent ☐ Tidal

Stream Type
☐ Coldwater ☑ Warmwater

...ES	**Predominant Surrounding Landuse** ☑ Forest ☐ Commercial ☐ Field/Pasture ☑ Industrial ☐ Agricultural ☐ Other ______ ☐ Residential **Local Watershed NPS Pollution** ☐ No evidence ☑ Some potential sources ☐ Obvious sources **Canopy Cover** ☐ Partly open ☐ Partly shaded ☐ Shaded **High Water Mark** ______ m **Local Water Erosion** ☐ None ☑ Moderate ☐ Heavy **Estimated Stream Width** 6 m **Estimated Stream Depth** ☐ Riffle .2 m ☐ Run .5 m ☐ Pool .7 m **Velocity** 1.2 ft/sec m/sec **Estimated Reach Length** 100 m **Channelized** ☐ Yes ☑ No **Dam Present** ☐ Yes ☑ No
RIPARIAN VEGETATION (18 meter buffer)	**Indicate the dominant type and record the dominant species present** ☑ Trees ☐ Shrubs ☐ Grasses ☐ Herbaceous **dominant species present** Hemlock, gum, poplar, sycamore, magnolia
AQUATIC VEGETATION	**Indicate the dominant type and record the dominant species present** ☐ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☐ Free Floating ☐ Floating Algae ☑ Attached Algae **dominant species present** ______ **Portion of the reach with vegetative cover** 5 %
SEDIMENT/ SUBSTRATE	**Odors** ☑ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other ______ **Oils** ☑ Absent ☐ Slight ☐ Moderate ☐ Profuse **Deposits** ☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand ☐ Relict shells ☐ Other ______ **Looking at stones which are not deeply embedded, are the undersides black in color?** ☐ Yes ☑ No
WATER QUALITY	**Temperature** ______ °C **Specific Conductance** ______ **Dissolved Oxygen** ______ **pH** ______ **Turbidity** ______ **WQ Instrument Used** ______ **Water Odors** ☑ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other ______ **Water Surface Oils** ☐ Slick ☐ Sheen ☐ Globs ☐ Flecks ☑ None ☐ Other ______ **Turbidity (if not measured)** ☑ Clear ☐ Slightly turbid ☐ Turbid ☐ Opaque ☐ Water color ☐ Other ______

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	**Diameter**	**% Composition in Sampling Reach**	**Substrate Type**	**Characteristic**	**% Composition in Sampling Area**
Bedrock		5	Detritus	sticks, wood, coarse plant materials (CPOM)	100
Boulder	> 256 mm (10")	20			
Cobble	64-256 mm (2.5"-10")	35	Muck-Mud	black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1"-2.5")	35			
Sand	0.06-2mm (gritty)	5	Marl	grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	< 0.004 mm (slick)				

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Licks Br	LOCATION @ Cyprus Amax Rd
STATION # 14 RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY EPA / KY DOW
INVESTIGATORS Howard / Weldon / Call	
FORM COMPLETED BY Howard et al	DATE 5/4/00 TIME 1005 (AM) PM — REASON FOR SURVEY KY MTM/VF

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut bank, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 (4) 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 (14) 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 (7) 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
Channel Iteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
. Frequency of riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; Infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 (7) 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank (10) 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 (7) 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank (10) 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 (7) 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

Total Score ___

52

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME Licks Br	LOCATION @ Cypress AMAX Rd
STATION # 14 RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY EPA / KyDOW
INVESTIGATORS Howard / Weldon / Call	
FORM COMPLETED BY Howard et al	DATE 5/4/00 1005 (AM) PM — REASON FOR SURVEY Ky MTM/VF

SITE LOCATION/MAP	Draw a map of the site and indicate the areas sampled
Sta 14	pix # 29 upstream - mid-pt 30 downstream mid-pt
Sta. 14-D (Duplicate Benthos)	pix # 31 upstream, mid pt 32 down-stream, mid pt

HABITAT TYPES	Indicate the percentage of each habitat type present ☑ Cobble ____% ☐ Snags ____% ☑ Undercut Banks ____% ☐ Sand ____% ☐ Submerged Macrophytes ____% ☑ Other (Leaf packs) ____%
STREAM CHARACTERIZATION	Subsystem Classification ☑ Perennial ☐ Intermittent ☐ Tidal Stream Type ☐ Coldwater ☑ Warmwater

RIPARIAN ZONE/ INSTREAM FEATURES		
	Predominant Surrounding Landuse ☑ Forest ☐ Commercial ☐ Field/Pasture ☐ Industrial ☐ Agricultural ☐ Other ______ ☐ Residential	**Local Watershed Erosion** ☑ None ☐ Moderate ☐ Heavy **Estimated Stream Width** 12'
	Local Watershed NPS Pollution ☐ No evidence ☑ Some potential sources (road?) [illegible] ☐ Obvious sources	**Estimated Stream Depth** ☐ Riffle 6-10" ☐ Run 1' ☐ Pool ______ m **Velocity** 1.67 ft/sec
	Canopy Cover ☐ Partly open ☑ Partly shaded ☐ Shaded	**Estimated Reach Length** 100 m
	High Water Mark 4'	**Channelized** ☐ Yes ☑ No **Dam Present** ☐ Yes ☑ No
RIPARIAN VEGETATION (18 meter buffer)	**Indicate the dominant type and record the dominant species present** ☑ Trees ☐ Shrubs ☐ Grasses ☐ Herbaceous *dominant species present* ______	
AQUATIC VEGETATION N/A	**Indicate the dominant type and record the dominant species present** ☐ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☐ Free Floating ☐ Floating Algae ☐ Attached Algae **dominant species present** ______ **Portion of the reach with vegetative cover** ____%	
SEDIMENT/ SUBSTRATE	**Odors** ☑ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other ______ **Oils** ☑ Absent ☐ Slight ☐ Moderate ☐ Profuse	**Deposits** ☐ Sludge ☐ Sawdust ☐ Paper fiber ☑ Sand ☐ Relict shells ☐ Other ______ **Looking at stones which are not deeply embedded, are the undersides black in color?** ☑ Yes ☐ No
WATER QUALITY	**Temperature** ______ °C **Specific Conductance** ______ **Dissolved Oxygen** ______ **pH** ______ **Turbidity** ______ **WQ Instrument Used** ______	**Water Odors** ☑ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other ______ **Water Surface Oils** ☐ Slick ☐ Sheen ☐ Globs ☐ Flecks ☑ None ☐ Other ______ **Turbidity (if not measured)** ☐ Clear ☑ Slightly turbid ☐ Turbid ☐ Opaque ☐ Water color ☐ Other ______

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)

Substrate Type	Diameter	% Composition in Sampling Reach
Bedrock		
Boulder	> 256 mm (10")	5
Cobble	64-256 mm (2.5"-10")	40
Gravel	2-64 mm (0.1"-2.5")	~~20~~ 25
Sand	0.06-2mm (gritty)	20
Silt	0.004-0.06 mm	10
Clay	< 0.004 mm (slick)	

ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)

Substrate Type	Characteristic	% Composition in Sampling Area
Detritus	sticks, wood, coarse plant materials (CPOM)	10
Muck-Mud	black, very fine organic (FPOM)	
Marl	grey, shell fragments	

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

FINAL REPORT

A Survey of the Water Quality of Streams in the Primary Region of Mountaintop / Valley Fill Coal Mining

October 1999 to January 2001

April 8, 2002

Mountaintop Mining / Valley Fill
Programmatic Environmental Impact Assessment

Prepared by:

Gary Bryant
Scott McPhilliamy
USEPA Region III
Wheeling, WV

and

Hope Childers
Signal Corporation
Wheeling, WV

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Contract Oversight - Jeffery Alper

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1. SUMMARY

1.1 Background

The Project Plan was designed to characterize and compare impacts to stream chemistry from mountaintop mines and associated valley fills (MTM/VF). This study used the same 37 stream monitoring sites used in the aquatic biology study of this same region. Most sites were visited, sampled, and had flow rate measured 13 times between October 1999 and February 2001 by field crews who are Mine Inspectors for the state of West Virginia. Four field parameters and 37 laboratory parameters were selected to be monitored at each site. Ten of those parameters had stream water quality criteria limits which were used to set measurement detection limits. One set of duplicate samples and two blank samples were to be collected each day by each field crew to enable assessment of sampling errors and sampling precision. The field work exceeded the goal of 90% completeness for site visits, steam sampling, flow measurements, and duplicate samples, but only 83 % of the number of blank samples were collected.

The contract for chemistry analyses was changed to a second laboratory in July 2000. EPA Region III chemists provided a QA/QC review of the laboratory data. Only 83 % of the values reported by the first laboratory passed the QA/QC review. The second laboratory had 98% of their data pass the QA/QC review. Corrective actions were implemented during the study to resolve problems in the field and laboratory. The data from this study is stored in a relational database which is part of this report.

1.2 Evaluation of Results

The results were evaluated and are presented under three lines of reasoning: 1) parameters altered by MTM/VF mining; 2) parameters violating stream water quality standards; 3) parameters not detected in any sample. Parameters likely to be impacted by MTM/VF mining were identified and used as an outline for evaluating the entire database from all categories of sites. Variations in data quality were assessed using the results of the duplicate samples and blank samples. Additional characterization of the categories of sites is provided by calculation of “Yield”rates, an idea taken from a USGS publication.

The data indicate that MTM/VF mining activities increase concentrations of the several parameters in streams. Sites in the category Filled had increased concentrations of the following parameters: sulfate, total calcium, total magnesium, hardness, total dissolved solids, total manganese, dissolved manganese, specific conductance, total selenium, alkalinity, total potassium, acidity, and nitrate/nitrite. There were increased levels of sodium at sites in the category Filled/Residences which may be caused by road salt and/or sodium hydroxide treatment of mine discharges.

The data were inconclusive for several other parameters which were detected in only a few samples or at very low concentrations. Those parameters: total phosphorous, total copper, total lead, total nickel, total barium, total zinc, total organic carbon, dissolved organic carbon, and total suspended solids. Other parameters were detected but there was no clear indication of stream impacts resulting from MTM/VF mining operations. Those parameters are: chloride, total aluminum, dissolved aluminum, total iron, dissolved iron, temperature, dissolved oxygen, and pH. Data from the second laboratory indicated that only three samples for total aluminum exceeded the stream criterion and all were collected August 9, 2000at sites with fills upstream. Dissolved aluminum was detected in only five samples and all were near the detection limit of 100 ug/L. There were no samples for total iron exceeding the stream criterion but several samples in the category Filled approached the limit in the fall of 2000. Dissolved iron was detected at a few sites in the category Filled at levels slightly higher than other sites. MTM/VF mining operations can increase iron concentrations in streams but there is no clear evidence that this occurred during the study. Temperature, pH, conductivity, and dissolved oxygen were measured in the field. The only field parameter clearly impacted by MTM/VF mining was conductivity which was noticeably increased at sites in the category Filled.

Parameters which were not detected in any sample analyzed at the second laboratory were: total arsenic, total antimony, total cadmium, total chromium, total cobalt, total vanadium, total thallium, total beryllium, total mercury, and total silver. Hot acidity was analyzed for a few samples and none was detected.

Only the data from the second half of the study was used to evaluate compliance with stream limits due to problems with contamination in blanks, excessive holding times and less precision which occurred during the first part of this study. The latter data indicate that MTM/VF mining is associated with violations of the stream water quality criteria for total selenium. Selenium violations were detected in each of the five study watersheds and all were at sites in the category Filled, downstream of MTM/VF operations. No other site categories had violations of the selenium limit. There were no violations of the limits for total beryllium, chloride, total mercury, total silver, temperature. The data do not support a conclusion regarding stream water quality violations for aluminum, dissolved oxygen, iron and pH which can be impacted by MTM/VF mining activities.

While outside the scope of this report, there would be value in having experts evaluate the flow rate data from this study to identify impacts attributable to mining. Base flows of streams with valley fills are reported to be 6 to 7 times greater than the base flows of unmined areas. During base flow conditions, the more highly mineralized water from fills becomes a larger portion of stream flow, altering the stream water chemistry.

2. STUDY OBJECTIVES

The final Project Plan for this study listed two objectives:

- Characterize and compare conditions in three categories of streams:
  1) streams that are not mined;
  2) streams in mined areas with valley fills; and
  3) streams in mined areas without valley fills.

- Characterize conditions and describe any cumulative impacts that can be detected in streams downstream of multiple fills.

This study was designed to supplement other studies of stream water quality impacts resulting from mountaintop mining and valley fill (MTM/VF) coal mining operations. This study compliments the aquatic biology study for this same region by gathering chemistry data on the same stream sites used by USEPA Biologists in their evaluation of MTM/VF impacts to aquatic organisms. The aquatic biology study report by Green, Passmore, and Childers is titled A Survey of the Condition of Streams in the Primary Region of Mountaintop Mining/Valley Fill Coal Mining. A separate report is being prepared to evaluate the relationships between the chemical data and biological data.

3. THE PROJECT PLAN

A Project Plan was drafted for this study in the summer of 1999 under the direction of the Environmental Impact Statement Steering Committee. The plan was posted on EPA Region III's web site. The plan was revised several times as the study progressed in response to comments and problems encountered during the study.

3.1 Monitoring Sites Description

The thirty seven (37) stream monitoring sites are exactly the same sites used by the USEPA Biologists in their study of MTM/VF. They provide a synoptic survey of stream conditions in five watersheds across the primary MTM/VF region in West Virginia. These watersheds are Twentymile Creek, Clear Fork, Island Creek, upper Mud River and Spruce Fork. The locations of the sites are shown in Figure 1. They are spread across the region of mountaintop mining in West Virginia. The sites were selected with the experienced assistance of WVDEP Mine Inspectors familiar with mining activities in the region and with the cooperation of coal companies in the area.

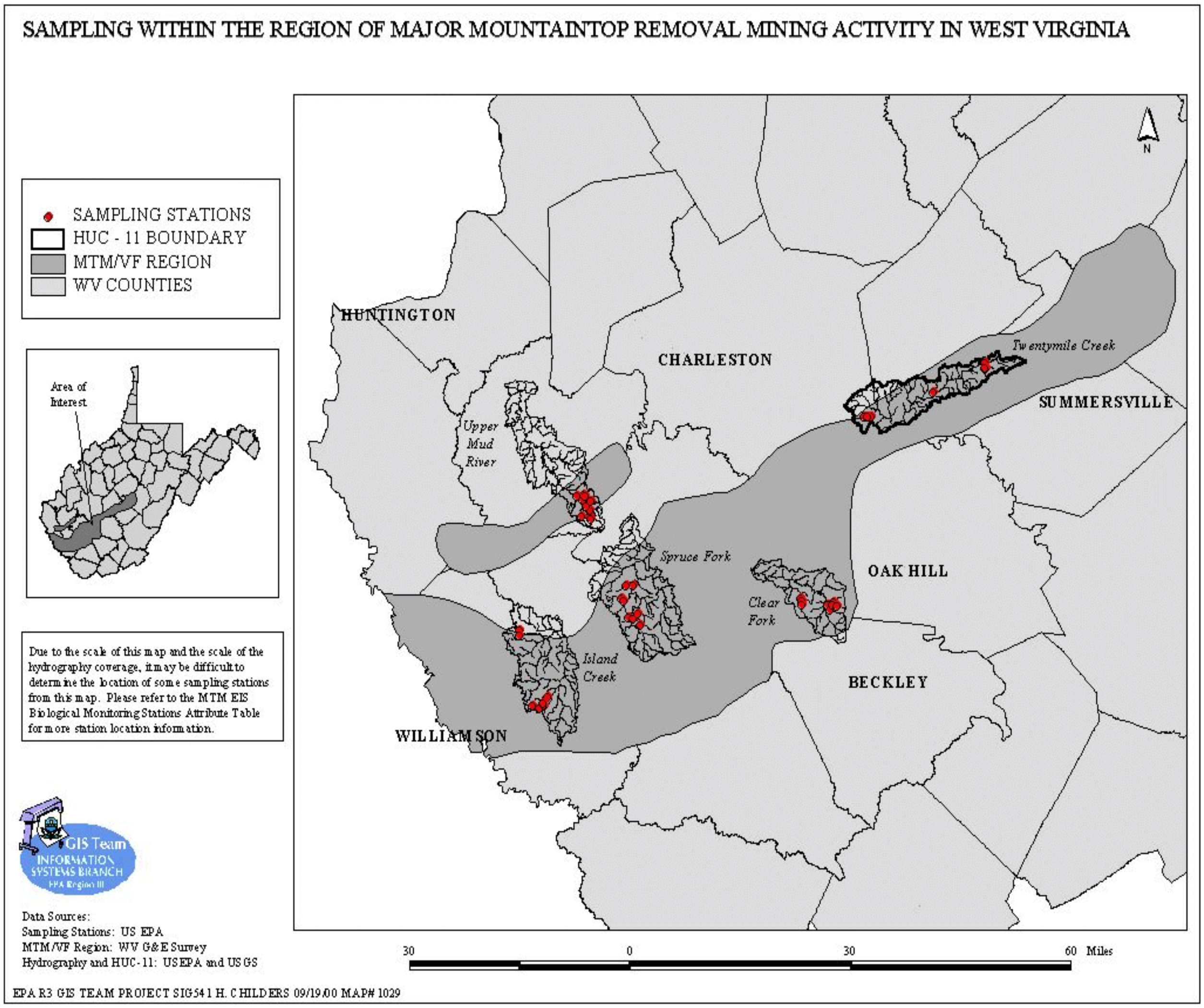

SAMPLING WITHIN THE REGION OF MAJOR MOUNTAINTOP REMOVAL MINING ACTIVITY IN WEST VIRGINIA
SAMPLING STATIONS
HUC - 11 BOUNDARY
MTM/VF REGION
WV COUNTIES
Area of Interest
Due to the scale of this map and the scale of the hydrography coverage, it may be difficult to determine the location of some sampling stations from this map. Please refer to the MTM EIS Biological Monitoring Stations Attribute Table for more station location information.
HUNTINGTON
CHARLESTON
SUMMERSVILLE
OAK HILL
BECKLEY
WILLIAMSON
Twentymile Creek
Upper Mud River
Spruce Fork
Clear Fork
Island Creek
N
30 0 30 60 Miles
GIS Team INFORMATION SYSTEMS BRANCH EPA Region III
Data Sources:
Sampling Stations: US EPA
MTM/VF Region: WV G&E Survey
Hydrography and HUC-11: USEPA and USGS
EPA R3 GIS TEAM PROJECT SIG541 H. CHILDERS 09/19/00 MAP# 1029

FIGURE 1. Map of Stream Sampling Site Locations

The distribution of sites within the three categories identified in the study objectives are:

1) streams that are not mined - Unmined -	9 sites
2) streams in mined areas with valley fills -	21 sites
(Filled 15sites + Filled/Residences 6 sites)	
3) streams in mined areas without valley fills -	6 sites
(Mined 4 sites + Mined/Residences 2 sites)	
Flow diversion ditch at a valley fill -	1 site
TOTAL	37 sites

The site numbers and descriptions are listed in Table 1. The station numbers are not sequential since the 37 biological sampling sites were chosen from 127 possible sampling sites. The sizes of the drainage areas upstream of the sites vary from 125 acres to 27,742 acres. Only three of the 37 sites have watersheds larger than 3,200 acres.

TABLE 1
Monitoring Site Attributes

Site Identification	EIS Class	Watershed	Area (acres)	No. of Fills	Comment/ Permit Date	No. of Visits	No. of Samples	No. of Flowrates
MT-01	Mined/Residence	upper Mud River	1,897		Past Logging	13	13	12
MT-02	Unmined	upper Mud River	511		Past Logging	13	13	12
MT-03	Unmined	upper Mud River	717		Past Logging	13	13	12
MT-13	Unmined	upper Mud River	335		Past Logging	13	12	12
MT-14	Filled	upper Mud River	1,527	8	‘85,’ 88, ‘89	13	13	12
MT-15	Filled	upper Mud River	1,114	6	‘88,’89,’91,’92’95	13	13	12
MT-18	Filled	upper Mud River	479	2	‘92, ‘’95	13	13	13
MT-23	Filled/Residence	upper Mud River	10,618	26	‘85,’88,’89,’91’92,’95 ,’96	13	13	12
MT-24	Ditch	upper Mud River	N/A	1	‘88, ‘91	13	13	13
MT-25B	Filled	Spruce Fork	997	1	‘86	13	13	13
MT-32	Filled	Spruce Fork	2,878	5	‘86,‘88,‘89,‘91	13	13	13
MT-34B	Filled	Spruce Fork	1,677		‘85, ‘86	13	13	13
MT-39	Unmined	Spruce Fork	669			13	13	13
MT-40	Filled/Residence	Spruce Fork	11,955	10	7 VF + 3 refuse	13	13	13
MT-42	Unmined	Spruce Fork	447			13	13	12
MT-45	Mined	Spruce Fork	1,111		‘87 strip @ head	13	13	13
MT-48	Filled/Residence	Spruce Fork	27,742	22	4 communities	13	13	13
MT-50	Unmined	Island Creek	563			13	13	12
MT-51	Unmined	Island Creek	1,172		gas well	13	11	10
MT-52	Filled	Island Creek	316	1	underground entry & fill / ‘84	13	13	13
MT-55	Filled/Residence	Island Creek	3,167	5	‘86,’88,’‘89, ‘93, ‘94, ‘98	13	13	12
MT-57B	Filled	Island Creek	125	1	‘88	12	12	11
MT-60	Filled	Island Creek	790	2	‘88, ‘93	13	13	12
MT-62	Filled/Residence	Clear Fork	3,193	11	‘89,’91,’92	14	14	14
MT-64	Filled	Clear Fork	758	5	‘92, ‘93	14	14	14
MT-69	Mined/Residence	Clear Fork	708		pre- ‘65	14	14	14
MT-75	Filled/Residence	Clear Fork	876	5	‘89, ‘92	14	14	14
MT-78	Mined	Clear Fork	524		pre- ‘65	14	2	2
MT-79	Mined	Clear Fork	448			14	14	14
MT-81	Mined	Clear Fork	1258		NaOH / pre ‘65	14	14	14
MT-86	Filled	Twentymile Creek	2,201	3	NaOH/ ‘90,’93	14	14	14
MT-87	Filled	Twentymile Creek	752	3	NaOH/’90,’93	14	14	14

MT-91	Unmined	Twentymile Creek	1,302		haul road	14	14	14
MT-95	Unmined	Twentymile Creek	968		logging?	14	14	14
MT-98	Filled	Twentymile Creek	1,208	8	‘77,’82,’90	14	14	14
MT-103	Filled	Twentymile Creek	1,027	6	‘77,’82,’90	14	14	13
MT-104	Filled	Twentymile Creek	2,455	8	‘77,’82,’90	14	14	14
Totals	37 sites					494	479	466

3.2 Monitoring Frequency

Stream samples were collected during the period of October 1999 thru February 2001. The sites were to be sampled monthly but the scheduling of when samples were taken was determined by availability of the field crews. The stream sampling effort was stopped in May 2000 due to problems with timely delivery of chemistry laboratory data. A contract was completed with a different laboratory and monthly sampling resumed in August 2000 and continued through February 2001. Most sites were visited 13 times for sampling. One field crew took an additional set of samples from the seven sites in Twentymile Creek in November 1999 and another crew took an additional set of sample from the seven sites in Clear Fork in June of 2000. A few times, some of the sites had no flow to sample. The field crew found stream flow on only two occasions at site MT-78. There were 479 stream samples collected in this survey, not counting the duplicates and other QA samples. Flow measurements were also made during sampling but there were several occasions when flows were not measured. This was especially true during winter months when the stream was frozen over. There were 467 flow measurements for this study. Table 1 lists this information for each sample site.

3.3 Monitoring Parameters and Sampling Methods

The parameters to be monitored were discussed by numerous groups and experts. The list of parameters finally selected was shaped by constraints of holding times, detection limits, difficulty in sampling and other factors. The discussion on what parameters to monitor began with a review the stream water quality parameters for the streams in the study area.

3.3.a Stream Water Quality Criteria

There are limits set on the concentrations of chemicals allowed in streams across the nation. Each State has established these stream water quality criteria for the surface waters of their State. West Virginia has three categories of stream water quality criteria set to protect specific water uses. Those categories of water uses are: 1) Aquatic Life, 2) Human Health, and 3) All Other Uses. The Aquatic Life Criteria are the limits most applicable to this study because those are designed to protect aquatic life in the stream. There can be separate limits for warm water and cold water (trout) streams. Sometimes there are also separate limits for acute and chronic exposure. Acute exposures would be those experienced during a short time period such as a spill. Chronic limits are usually lower than Acute limits since the organisms are exposed for a longer time period. Water quality criteria also vary with sample methods. Some criteria specify "Not to exceed" which is a grab sample of the stream. These criteria are applicable to the sampling methods used in this study. There are also some criteria set for a "one-hour average" which are not strictly applicable to the single grab sample results of this study, but they are still valuable in evaluating if there are concerns about the concentrations of chemicals identified in this study. The West Virginia Water Quality Criteria limits are discussed in Attachment 1.

3.3.b Mining Permit Monitoring

Coal companies seeking permits must monitor streams above and below their proposed mining sites as part of the process for getting a mining permit. It was agreed that the list of parameters being monitored for permits would be expanded to include the parameters being monitored in this study. Discussions with coal companies were held to invite their comments on the list of parameters. This list of "interim protocol" parameters was adopted for coal companies seeking permits in West Virginia. They were asked to monitor for the list of "interim protocol" parameters as part of their pre-mining data gathering effort. The data gathered by the coal companies and their consultants could also be used to in evaluating the impacts of mining but that data has not been included in this report. A separate report is being prepared using coal company data for this EIS effort.

3.3.c Laboratory Parameters

After much discussion and evaluation, the 37 chemical parameters listed below were selected for laboratory analyses. The samples were to be collected and preserved and analyzed following procedures consistent with 40 CFR Part 136.

Water Quality (10)

Acidity	Nitrate + Nitrite	Total Organic Carbon
Alkalinity	Sulfate	Dissolved Organic Carbon
Chloride	Total Suspended Solids	
Hardness	Total Dissolved Solids	

Total Metals (27)

Aluminum	Cobalt	Nickel
Dissolved Aluminum	Copper	Potassium
Antimony	Iron	Phosphorous
Arsenic	Dissolved Iron	Selenium
Barium	Lead	Silver
Beryllium	Magnesium	Sodium
Cadmium	Manganese	Thallium
Calcium	Dissolved Manganese	Vanadium
Chromium	Mercury	Zinc

Hot acidity was also analyzed for a brief period by the second laboratory by mistake.

3.3.d Field Parameters

Field crews were WVDEP Mine Inspectors. They were briefed in the standard monitoring procedures at the start of this study. The briefing included instructions in measuring Dissolved Oxygen, Specific Conductivity, Temperature, and pH *in situ* using calibrated electrometric field meters. The field chemistry measurements taken at each sampling site were consistent with 40 CFR Part 136. The field crew recorded measurements and other sample site information on field sheets which were sent to the lab with the samples. They also measured flow rate at the time of sampling using methods suitable for effluent discharge monitoring under the NPDES program. EPA office staff used a computer program to calculate stream flows from the field stream gaging data. A copy of the blank field sheets used in this study is included as ATTACHMENT 2.

3.4 Stream Sample Collection and Shipping

The laboratory provided sample containers, chemical preservatives, lab-pure water, labels, and shipping containers. They were shipped to the WVDEP field offices. The sampling procedures used were consistent with the 40 CFR Part 136 and samples were collected as grab samples in mid-stream. The samples were preserved and stored on ice in the shipping containers until they were ready to ship to the lab following chain-of-custody procedures. A separate field sheet for each sample, as shown in Attachment 2, was to be placed in the shipping containers.

3.5 Methods and Detection Limits for Water Quality Criteria Parameters

Ten of the parameters monitored during this study have an applicable stream water quality criteria. These criteria were used to select methods of analysis and detection limits for the laboratory analyses. The concern was that values reported by the laboratory as exceeding the stream criteria would be measured precisely enough to confidently say that stream criteria were exceeded. Therefore the detection limit or lowest measurable concentration reported by the laboratory was arbitrarily designated to be no greater than one third of the lowest applicable water quality criterion. The detection limit for this study was set after discussions with chemists as to what detection limits are achievable following excellent laboratory practices. The method selected and the detection limit for each parameter with a criterion are included in Table 2.

TABLE 2
Water Quality Criteria and Method Detection Limits

Parameter	*Water Quality Criterion*	*Method*	*Detection Limit*
Total Aluminum	750 ug/L	EPA 200.7	100 ug/L
Total Beryllium	130 ug/L	EPA 200.7	1 ug/L
Chloride	230 mg/L	EPA 300.0	5.0 mg/L
Dissolved Oxygen*	5.0 mg/L	Field Meter	0.1 mg/L
Total Iron	1.5 mg/L	EPA 200.7	0.10 mg/L
Total Mercury	2.4 ug/L	EPA 245.1	0.2 ug/L
pH*	6.0 to 9.0	Field Meter	0.1 pH unit
Total Selenium	5 ug/L	EPA 200.8	3 ug/L**
Total Silver	1 to 43 ug/L	EPA 200.7	10 ug/L
Temperature*	73^{O} or 87^{O} F	Field Meter	+/- 2^{O} F

* Field meter required to measure these parameters.
** The estimated instrument detection limit for selenium in water using Method 200.8 (Inductively Coupled Plasma - Mass Spectrometry) is around 5 ug/L according to the 1983 EPA Methods Manual.

4. DATA QUALITY REQUIREMENTS AND ASSESSMENTS

4.1 Field Work

The field work was conducted by personnel from the West Virginia Division of Environmental Protection, Office of Mining & Reclamation and reviewed by the EPA staff.

4.1.a Field Work Completeness Assessment

The project plan requires a monthly visit to each site, a sample from each site when there is flow, and a flow measurement. The field data are recorded on field sheets for each sample. The field crews sent copies of their field sheets to the EPA as well as to the contract labs with the samples. The EPA monitored the progress of the field work by reviewing and evaluating these field sheets. Some crews also reported problems and progress through telephone conversations with the EPA.

The data and notes from the field sheets was transferred to the electronic database by the EPA staff. All flow rates were calculated from the field readings by laboratory personnel or EPA staff using the same computer program. The electronic records were then completely checked for data entry errors. These records were then used to cross check the records and data received from the laboratories and the QA/QC review. The calibration records for field meters were not included in the electronic database of data for this study, but the comments from the field sheets are included.

4.1.b Field Work Sampling Errors Assessment

The Project Plan specified three types of QA samples be collected by each crew each day of sampling. **Field Duplicate Samples** were collected as two identical sets of stream samples from a stream monitoring site. The second set was labeled as a Duplicate Sample. The concentrations of each parameter in these pairs of Duplicate Samples should be nearly identical. **Blank Samples** were collected in a set of sample containers using lab-pure water from the laboratory and preserving them just like the stream samples, including filtering. These samples were called Blanks and the concentration of all parameters in each sample should be at or near the detection limit. The third type of QA sample used in this survey was a **Trip Blank Sample**. This was a set of sample containers filled with lab-pure water in the laboratory and sent to the field crews with the other sample containers and preservatives. This Trip Blank was opened in the field at the sample site and preserved as the stream samples, except there was no water filtered in the field in the Trip Blank. Any measurable concentrations parameters in these blank samples would indicate concerns with sample handling or contaminated sampling equipment. QA samples were tested in the laboratory for the same parameters as the stream samples. Although the QA samples were collected to evaluate problems with sample collection and handling in the field, they can also be used to detect errors in measurement which occur in the laboratory.

4.1.c Field Duplicates

Field Duplicate data can be used to calculate an estimate the precision of sampling methods. This estimate of precision includes error associated with field collections at the site, error in sample handling, and error associated with laboratory activities as well as true variation in the water being sampled. Since it is not possible to separate the variation caused by sampling error or sample handling error from the variation caused by measurement error, the differences between sets of duplicate samples can only give an estimation of precision in sampling. The estimate of precision in this study is based on laboratory results of Field Duplicate samples. Field Duplicate samples were to be collected at 10% of the sites on each sampling occasion (one Field Duplicate per sampling crew per day). Only the first of the two sets of sample results was used in calculating and evaluating the monitoring trends and statistics for a site.

Precision estimates were calculated from the data for Field Duplicate samples using **Relative Percent Difference (RPD)**. RPD is calculated using the following equation:

$$RPD = ((C_1 - C_2)x100) \div ((C_1 + C_2)/2)$$

where: C_1 = the larger of the two values and
C_2 = the smaller of the two values.

Often the smaller of the two values was below the minimum concentration the laboratory could detect (called the Detection Limit or DL). In calculating statistics on the concentration at a site, every time a reported value was below the DL, a value of one half the DL was assigned as the smaller value (C_2), rather than zero. The RPD varies with each parameter and for each set of duplicates. There are tables of RPD results for selected parameters in this report under the section Evaluation and Discussion of Results. As the concentrations in the duplicate samples approach the detection limit, the RPD values are not as meaningful an estimate of precision. There is a trend in the data from this study for the RPD to improve (get much lower) with later samples. This may be due to improvements in sample collection and handling in the field and laboratory or due to differences between the laboratories.

There is also a trend in the results from this study for the concentrations to be lower in the second half of the study. This may be due to lingering effects of the drought conditions experienced just before the beginning of the sampling in 1999. It could also result from improvements in sample collection and handling in the field and laboratory as the study progressed. It could also be due to differences between the two laboratories. There were detectable concentrations of arsenic, cadmium, lead, manganese, silver and thallium in results from the first laboratory but the second laboratory found no detectable concentrations of these metals in any samples. The first laboratory also reported generally higher concentrations of antimony and nickel than the second laboratory.

Another way to evaluate precision is to **plot concentration of duplicate samples**. The X-axis is the concentration of the first sample and the Y-axis is the concentration of second sample A point is plotted for each set of duplicate samples. If the values for all sets of duplicate samples are equal, they will make a straight line from the detection limit to the maximum value detected. This approach can be used on duplicate samples of stream samples as well as the duplicate sets of blank samples.

It is recognized that even the best laboratories can not "hit a bulls eye" every time with analytical tests so the study plan allows for a general "precision limit" of plus or minus 25%. The precision limits can also be plotted on the graph of duplicate sample results to illustrate when values of duplicate samples are "out of control" or beyond the precision limit. Graphs of duplicate sample results have been plotted for various parameters using a unique symbol for each laboratory. Errors in sample collection or handling in the field may cause duplicate samples to be "out of control," but the problem may also be in the laboratory. The plots of duplicate sample results also indicate the precision of the sampling at the second laboratory was much better than the first. This may be due to improvements with experience in collecting and handling samples in the field or it may be related to the laboratory. The end result is that there is more confidence in the precision of sample data from the later portion of the study. There were twice as many duplicate samples analyzed at the second laboratory and the sites were more varied with fewer Unmined sites. As a result the range of concentrations in duplicates is generally wider than at the first laboratory.

4.1.d Blanks

Field crews were to collect two blanks each day they sampled. Not all field crews were equally diligent in collecting and identifying Blank Samples. Problems were identified with each crew not always having the supply of lab pure water and adequate sample containers when they needed them. There were also other communication problems. There were intermittent problems with unacceptable concentrations of contaminants in the blank samples. Some problems were thought to have been caused by field errors such as putting the acid preservatives in the wrong bottle, but this was not confirmed. There was also an intermittent problem with inadequate supplies of lab pure water for blanks and at least one crew noted they purchased distilled water on two occasions to use in the blanks. The quality of the blank water was sometimes questioned by chemists running the samples. The data for all Field Blank samples has been evaluated as a group to identify variability among the parameters. The number of Field Blank samples with detectable concentrations of contamination for each laboratory are listed by parameter in Table 3.

Within the group of blank samples there were 28 pairs of duplicate blanks. These were duplicates for all parameters except those which were filtered in the field. The graph plots of these "duplicate blanks" for selected parameters are included in this report under the section Evaluation and Discussion of Results. The precision and amount of contamination revealed in these graphs indicates that the contamination of blanks decreased in data from the second laboratory. This could be due to improvements in sample handling in the field or in the laboratory. The end result is that there is less contamination of blank samples during the later portion of the study, and there are several parameters which have unreliable results from the first laboratory. The parameters with unreliable results from the first half of this study included acidity, alkalinity, antimony, arsenic, lead, phosphorous, potassium, selenium, thallium, and most critically both suspended and dissolved solids.

The Project Plan calls for sample results from a site to be "flagged" when the concentration of a parameter in the blank (field or laboratory blank) exceeds 1/10th of the value reported in the stream sample. The electronic spreadsheet of the data included as ATTACHMENT 3 has a column identifying all "flagged" data. The code letter "B" identifies results with problems with the excessive contamination in the blank samples.

TABLE 3
Contamination Detected in Blanks

PARAMETER	LAB 1 Number From 30 Samples Greater Than Detection Limit	LAB 2 Number From 50 Samples Greater Than Detection Limit
ACIDITY	28	0
ACIDITY HOT		0*
ALKALINITY	28	0
ALUMINUM, DISSOLVED	4	1
ALUMINUM, TOTAL	3	3
ANTIMONY, TOTAL	24	0
ARSENIC, TOTAL	25	0
BARIUM, TOTAL		0
BERYLLIUM, TOTAL	0	0
CADMIUM, TOTAL	0	0
CALCIUM, TOTAL	13	0
CHLORIDE	5	0
CHROMIUM, TOTAL	8	0
COBALT, TOTAL		0
COPPER, TOTAL	3	2
DISSOLVED, ORGANIC CARBON	3	4
IRON, DISSOLVED	1	0
IRON, TOTAL	4	1
LEAD, TOTAL	24	1
MAGNESIUM, TOTAL	8	0
MANGANESE, DISSOLVED	1	0
MANGANESE, TOTAL	3	1
MERCURY, TOTAL	0	1
NICKEL, TOTAL	12	0
NITRATE	5*	0*
NITRITE	0*	0*
NITRATE+NITRITE	0*	0*
PHOSPHORUS, TOTAL	22	0
POTASSIUM, TOTAL	28	0
SELENIUM, TOTAL	21	1
SILVER, TOTAL	0	0
SODIUM, TOTAL	15	0
SULFATE	1	0
THALLIUM, TOTAL	20	0
TOTAL DISSOLVED SOLIDS	27	1
TOTAL ORGANIC CARBON	3	2
TOTAL SUSPENDED SOLIDS	26	0
VANADIUM, TOTAL		0
ZINC, TOTAL	11	9

* The number of Blank samples for these parameters is less than for other parameters.

4.1.e Field Work Completeness Evaluation

Completeness is a quality assurance/quality control term and is defined as the measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. Completeness was measured by calculating what percentage of samples were collected and analyzed with valid results. The goal for this project was 90% completeness. Completeness is calculated according to the following equation.

$C = 100 \times (V/N)$
where: C = percent completeness
V = number of measurements judged valid
N = total number of measurements.

The percent completeness was calculated for the field work and is presented in Table 4.

TABLE 4
Field Work Data Summary

Factor Being Measured	**Numbers (V and N)**	**Percent Completeness**
Attempted Visits to Sites	495 of 495	100
Actual Visits to Sites	494 of 495 Attempts	99.8
Number of Times Sites Dry @ Visit	15	N/A
Number of Samples at Sites	479* of 494 Visits	97.0
Number of Flow Measurements	466 of 479 Samples	97.3
Number of Duplicate Sample Sets	44 of 479 Samples	9.18% / 10% Goal = 91.8%
Number of Blank Samples	80 of 479 Samples	16.7% / 20% Goal = 83.5%

*Excluding the Duplicate and Blank samples.

The field work was especially complete in this study. There was only one occasion during this entire survey when a field crew could not reach a site. A tree had fallen and blocked the road to site MT-57B on September 28, 2000. The percent completeness is 494 visits out of 495 attempts or 99.8 %. This was excellent and greatly exceeded the goal of 90% completeness.

Samples were collected at all sites on every visit unless the streams were dry. Site MT-78 was dry12 times in this study. In the entire study, there were only 15 site visits which found no stream flow. There were 479 stream samples collected in this survey, not counting duplicates and other QA samples. The percent completeness is 479 samples out of 494 visits or 97.0 %. This was excellent.

Flow rate was to be measured on each sampling occasion. The crews were generally able to measure flows with each round of sampling. However, when they made the sample runs in January of 2001 they found 12 stream sites were covered with ice and stream flows were not measured. The total number of missed flow measurements in this study was only 13. The percent completeness is 466 flows out of 479 samples or 97.3 %. This was also an excellent effort from the field crews.

The goal for field duplicate samples listed in the project plan was to have duplicate analyses performed on 10% of the sites on each sampling occasion. Field crews did not collect any duplicate samples until March 2000 due to several problems with supplying an adequate number of sample containers as well as confusion. From March 2000 on, the crews sampled duplicates as in the work plan. There were 44 duplicates for 479 samples so overall the study performed duplicate analyses on 9.18 % of the sites sampled.

The work plan did not list a numeric goal for the collection of blank samples but the ideal number of blanks should have been 20% of the number of samples. Field crews did not all collect blank samples the same way nor on each sampling day for several reasons. There was an intermittent problem with inadequate supplies of extra sample bottles and lab pure water. There were also communication problems which continued until the end of the study. Some crews collected two sets of blank samples each sampling day calling one set the Field Blank and the other set the Trip Blank. There were 28 pairs of blank samples (56 samples) collected during this study. There were 23 solitary blank samples collected and one day when three blank samples were collected by one crew. There were a total of 80 blank samples collected during the study for 479 samples for a percentage ratio of 16.7%. This falls short of the goal. Although the number of blank samples was high, they were not collected as planned and the differences between crews did not get resolved during the study.

4.2 Laboratory Work

The chemistry analyses of the samples were performed by contractor laboratories. The first lab appeared to be unable to keep up with the work load. Samples were not analyzed within allowable holding times and there were unacceptable delays in submitting laboratory reports and records. In July 2000, a second contract laboratory took over the chemistry analytical work and continued to the end of the study.

EPA Region III's Office of Analytical Services and Quality Assurance (OASQA) developed the plans for doing the QA/QC review of the laboratory data. The data validation process was consistent with those listed in the "*Innovative Approaches for Validation of Organic and Inorganic Data-SOPs*", June 1995, Section IM-1, entitled: "*Validation of Target Analyte List Metals and Cyanide Data, Manual Approach IM-1*." The review process was designed using experience from the QA/QC procedures that EPA uses in overseeing the Contract Laboratory Program (CLP). The plan was modified when the contract was developed for the second laboratory to focus on a thorough review of 10% of the data. All data from sites MT-03, MT-15, MT-24, and MT32 for the following ten analytes were recalculated by EPA chemists: Sulfate,

(NO_2+NO_3)-N, TOC, DOC, Total Iron, Total Aluminum, Total Manganese, Dissolved Iron, Dissolved Aluminum, Dissolved Manganese. They continued to review the reports to confirm that good laboratory practices were being followed with regard to lab methods, detection limits, spiked samples, etc.

Both laboratories evaluated accuracy by preparing and analyzing duplicate spiked samples. The matrix spiked and matrix spiked duplicate (MS/MSD) results were included in the QA/QC review. The parameters which had MS/MSD evaluations were sulfate, chloride, nitrate-nitrite, total phosphorous, total metals, dissolved metals, total organic carbon, and dissolved organic carbon.

4.2.a Data Submission

The data reports from the laboratory were sent to the EPA QA/QC staff. The following additional items were included in each laboratory report: Name and location of laboratory; signature of the Laboratory Director (approval signature); project name; report date; stations; date and time of sampling; laboratory sample ID; listing of all problematic quality control items (for that set of samples) and supporting documentation of the necessary corrective action/s; analytical methods used for each parameter; date of analysis for each analyte; units; analytical results; results for laboratory and field blanks (field blanks are identified by samplers to the lab); sequential page number with total number of pages indicated; fully defined header information with tables of QC results; QC acceptance limits for each QC result; results of preservations checks; MDLs for each analyte and referenced procedure; the QC results summary in each data package is to be limited to that associated with the samples in a months data package; the date and time or position in the analysis sequence of the analysis of QC sample (included in each QC sample result summary for each month); quantitation limits and a reference to method for establishing the QL (e.g. $\geq$3*MDL); and all calibration, analysis run logs, and sample "raw data" (instrument readings) for the key sites and parameters monitored, to allow the reconstruction of the analytical results, as part of data validation for this project. Additional supporting analytical data was requested if problems were encountered in performing the data validation. The report included the analytical results for the sample set, any QA/QC problems encountered during the analyses; changes in the QAPP; and data quality assessment in terms of precision, accuracy, representativeness, completeness, and comparability.

EPA chemists developed checklists and codes for different QA/QC issues or concerns they might find. They used these checklists in their review of the laboratory reports for compliance with QA/QC requirements. They made notes on the laboratory reports using the codes and guidelines they had developed. Those are described in this report in the section *Data Qualifiers or Flags*. Once the QA/QC review of the reports was completed, the original laboratory records were placed in storage. Copies of the lab reports with the handwritten codes were sent to the Project Officer and report writers.

The laboratories provided an electronic record of the chemistry results for most of the samples. The transfer of these data into the electronic database for this study is described in this report in the section *Database of Results*.

4.2.b Data Qualifiers or Flags

EPA Region III Chemists performed the quality review of the analytical data evaluating methods, holding times, preservatives, minimum detection limits (MDL), back calculation of results from lab bench sheets, and compliance with good laboratory practices. Based on this review they assigned "Qualifiers" or "flags" to the data. In general the qualifiers were either Estimates or Rejects.

Estimate codes were assigned in the following categories:

B	No filter blank for DOC or Dissolved Metals, or the blank results exceed 1/10 the sample results.
C	Calibration not performed or documented, or the results vary from the standard concentration by more than 20%.
D	Minimum Detection Limit exceeds QAPP specifications.
H	Holding Times not documented or beyond specification in 40 CFR Part 136.
M	Method not specified or not complying with 40 CFR Part 136.
P	Proper preservative not used or not documented.
Q	Matrix spikes outside of specifications for recovery limits (either lab limits or +/- 25%) or RPD of duplicate spikes beyond precision limits (either lab limits or < 20% RPD). 10 % of samples for selected parameters were to include a matrix spike.
?	Other (e.g. N.D. = no raw data to support result for critical stations and parameters).

Reject codes were assigned for the following categories:

R(H)	Holding time two days or more beyond the required holding time.
R(B)	Sample value did not exceed the level in the laboratory blank or field blank.
R(?)	Reject for other specified reason.

These flagging codes were hand written on the lab reports during the QA/QC review by the Chemists. EPA staff reviewed the coded lab reports and identified all the data flagged as Rejected. Some additional data was rejected after further evaluation by the report writers after reviewing field and lab notes. These "flags" were entered in the electronic spreadsheet for this study and cross checked for data entry errors. **No rejected data has been included in any statistical evaluations of stream quality for this study.**

Significant amounts of data from the first lab were rejected in the QA/QC review. Roughly 60 % of the values were rejected for Total Suspended Solids, Total Dissolved Solids, Total Phosphorous, and Total Mercury. Overall about 20% of the entire data set from the first laboratory rejected. The data quality from the second laboratory was much better. The second laboratory had fewer problems with excessive holding times and very little contamination of blanks. The same codes for data qualifiers or flags were used by the EPA Chemists reviewing the data. Again codes were manually written on a lab report form and EPA staff reviewed the coded lab reports and identified all the data flagged as Rejected. They entered these "flags" in the electronic spreadsheet for this study and cross checked this entire data entry effort. **No rejected data has been included in any statistical evaluations of stream water quality for**

this study.

4.2.c Laboratory Data Completeness Evaluation

Completeness of the entire data set varies with each parameter and with each laboratory. Completeness is calculated according to the following equation:

$$C = ((N - R) \div N) \times (100)$$

where: C = percent completeness
N = total number of values
R = number of values flagged as Rejected

The percent completeness of each parameter is included in Table 5. The percent completeness for the entire dataset is 89.7 %, just missing the goal of 90%. The first laboratory achieved 82.77 % while the second laboratory achieved 97.88 %. The most common cause of rejection was when the first laboratory failed to perform the analyses within the holding times specified in the Method. This was especially true for sulfate, chloride, total suspended solids, total dissolved solids, mercury, nitrate, and nitrite. Even though the second laboratory achieved 100 % completeness for sulfate, chloride, total suspended solids, total dissolved solids, and total phosphorous, the overall percent completeness for those parameters fell short of the goal of 90%. The second laboratory analyzed for (NO_2+NO_3)-N instead of nitrate and nitrite so the percent completeness values for those each of those parameters is from only one laboratory. The data in Table 5 indicate that several other parameters were analyzed at only one laboratory. Several parameters were reported at the second laboratory only due to automated procedures which include groups of parameters, beyond what was tested at the first laboratory.

The changes to levels of organic nutrients in the stream was a concern which initiated the monitoring for total organic carbon (TOC) and dissolved organic carbon (DOC). The values found in this study were consistently near the limits of measurability and there appeared to be something leach from the filter which interfered in the analysis causing the dissolved concentration to be higher than the total concentration. For this reason many of the values for TOC and DOC were rejected, resulting in the very low percent completeness for those two parameters. Several values for total and dissolved metals were also rejected in the QA review when the dissolved value exceeded the total value. This resulted in the lower percent completeness values for aluminum, iron and manganese.

TABLE 5
Percent Completeness for Analytical Results by Laboratory

ANALYTE	UNITS	LAB 1 - # SAMPLES	LAB 1 - # SAMPLES NOT REJECTED	LAB 1 - % COMPLETE	LAB 2 - # SAMPLES	LAB 2 - # SAMPLES NOT REJECTED	LAB 2 - % COMPLETE
ACIDITY	**mg/l**	**266**	**208**	**78.20**	**191**	**191**	**100.00**
ALKALINITY	**mg/l**	**266**	**265**	**99.62**	**213**	**213**	**100.00**
ALUMINUM, DISSOLVED	**ug/l**	**266**	**234**	**87.97**	**213**	**213**	**100.00**
ALUMINUM, TOTAL	**ug/l**	**266**	**221**	**83.08**	**213**	**212**	**99.53**
ANTIMONY, TOTAL	**ug/l**	**266**	**251**	**94.36**	**213**	**213**	**100.00**
ARSENIC, TOTAL	**ug/l**	**266**	**264**	**99.25**	**213**	**213**	**100.00**
BARIUM, TOTAL	**ug/l**				**213**	**213**	**100.00**
BERYLLIUM, TOTAL	**ug/l**	**266**	**257**	**96.62**	**213**	**213**	**100.00**
CADMIUM, TOTAL	**ug/l**	**266**	**266**	**100.00**	**213**	**213**	**100.00**
CALCIUM, TOTAL	**ug/l**	**266**	**264**	**99.25**	**213**	**213**	**100.00**
CHLORIDE	**mg/l**	**266**	**161**	**60.53**	**213**	**213**	**100.00**
CHROMIUM, TOTAL	**ug/l**	**266**	**245**	**92.11**	**213**	**213**	**100.00**
COBALT TOTAL	**ug/l**				**213**	**213**	**100.00**
COPPER, TOTAL	**ug/l**	**266**	**255**	**95.86**	**213**	**211**	**99.06**
DISSOLVED, ORGANIC CARBON	**mg/l**	**266**	**208**	**78.20**	**213**	**170**	**79.81**
HARDNESS, TOTAL	**mg/l**				**212**	**212**	**100.00**
IRON, DISSOLVED	**ug/l**	**266**	**222**	**83.46**	**213**	**208**	**97.65**
IRON, TOTAL	**ug/l**	**266**	**208**	**78.20**	**213**	**205**	**96.24**
LEAD, TOTAL	**ug/l**	**266**	**255**	**95.86**	**213**	**213**	**100.00**
MAGNESIUM, TOTAL	**ug/l**	**266**	**266**	**100.00**	**213**	**213**	**100.00**
MANGANESE, DISSOLVED	**ug/l**	**266**	**228**	**85.71**	**213**	**210**	**98.59**
MANGANESE, TOTAL	**ug/l**	**266**	**218**	**81.95**	**213**	**210**	**98.59**
MERCURY, TOTAL	**mg/l**	**266**	**129**	**48.50**	**213**	**174**	**81.69**
NICKEL, TOTAL	**ug/l**	**266**	**239**	**89.85**	**213**	**213**	**100.00**
NITRATE+NITRITE (N)	**mg/l**				**212**	**199**	**93.87**
NITRATE	**mg/l**	**266**	**144**	**54.14**			
NITRITE	**mg/l**	**266**	**175**	**65.79**			
PHOSPHORUS, TOTAL	**mg/l**	**266**	**106**	**39.85**	**213**	**213**	**100.00**
POTASSIUM, TOTAL	**mg/l**	**266**	**264**	**99.25**	**213**	**213**	**100.00**
SELENIUM, TOTAL	**ug/l**	**266**	**259**	**97.37**	**213**	**210**	**98.59**
SILVER, TOTAL	**ug/l**	**266**	**266**	**100.00**	**213**	**213**	**100.00**
SODIUM, TOTAL	**mg/l**	**266**	**265**	**99.62**	**213**	**213**	**100.00**
SULFATE	**mg/l**	**266**	**171**	**64.29**	**213**	**213**	**100.00**
THALLIUM, TOTAL	**ug/l**	**266**	**250**	**93.98**	**213**	**213**	**100.00**
TOTAL DISSOLVED SOLIDS	**mg/l**	**266**	**116**	**43.61**	**213**	**213**	**100.00**
TOTAL ORGANIC CARBON	**mg/l**	**266**	**206**	**77.44**	**213**	**180**	**84.51**
TOTAL SUSPENDED SOLIDS	**mg/l**	**266**	**115**	**43.23**	**213**	**213**	**100.00**
VANADIUM, TOTAL	**ug/l**				**213**	**213**	**100.00**
ZINC, TOTAL	**ug/l**	**266**	**244**	**91.73**	**213**	**199**	**93.43**
TOTALS FOR EACH LAB		**9310**	**7706**	**82.77**	**7857**	**7690**	**97.88044**
OVERALL % COMPLETENESS							**89.70**

4.3 Corrective Actions

There was a problem early in the study with the field crews not collecting the proper number of Field Duplicate samples. None were collected during the first four rounds of samples. The problem was resolved through increased communication and coordination with the laboratory and field crews. From March through the end of the study, the crews usually collected one duplicate sample every day they were sampling. Field Duplicates made up more than 10% of the samples being collected after March of 2000.

There was also a problem early in the study with the field crews not collecting Blank Samples each day which were to be processed and analyzed just like the stream samples. There was continuing confusion regarding collection and preservation of Blank Samples. Some field crews collected two sets of Blank Samples each day calling one set a Trip Blank and the other set a Field Blank. There was also an intermittent problem with some crews not having adequate supplies of sample containers and lab pure water for the blanks. There was a meeting to improve coordination with the field crews and the laboratory prior to the start of work with the second laboratory, but the Blanks continued to be called different names by different crews.

There were problems with the quality of laboratory data and supporting information during this study forcing a change of laboratories performing the analyses. Timely submission of the laboratory data for QA review by EPA staff was a problem throughout the study. Corrective actions taken included requiring submission of corrections to laboratory reports and submission of additional records. The improvement in percentage completeness between the two laboratories indicates success of the corrective actions.

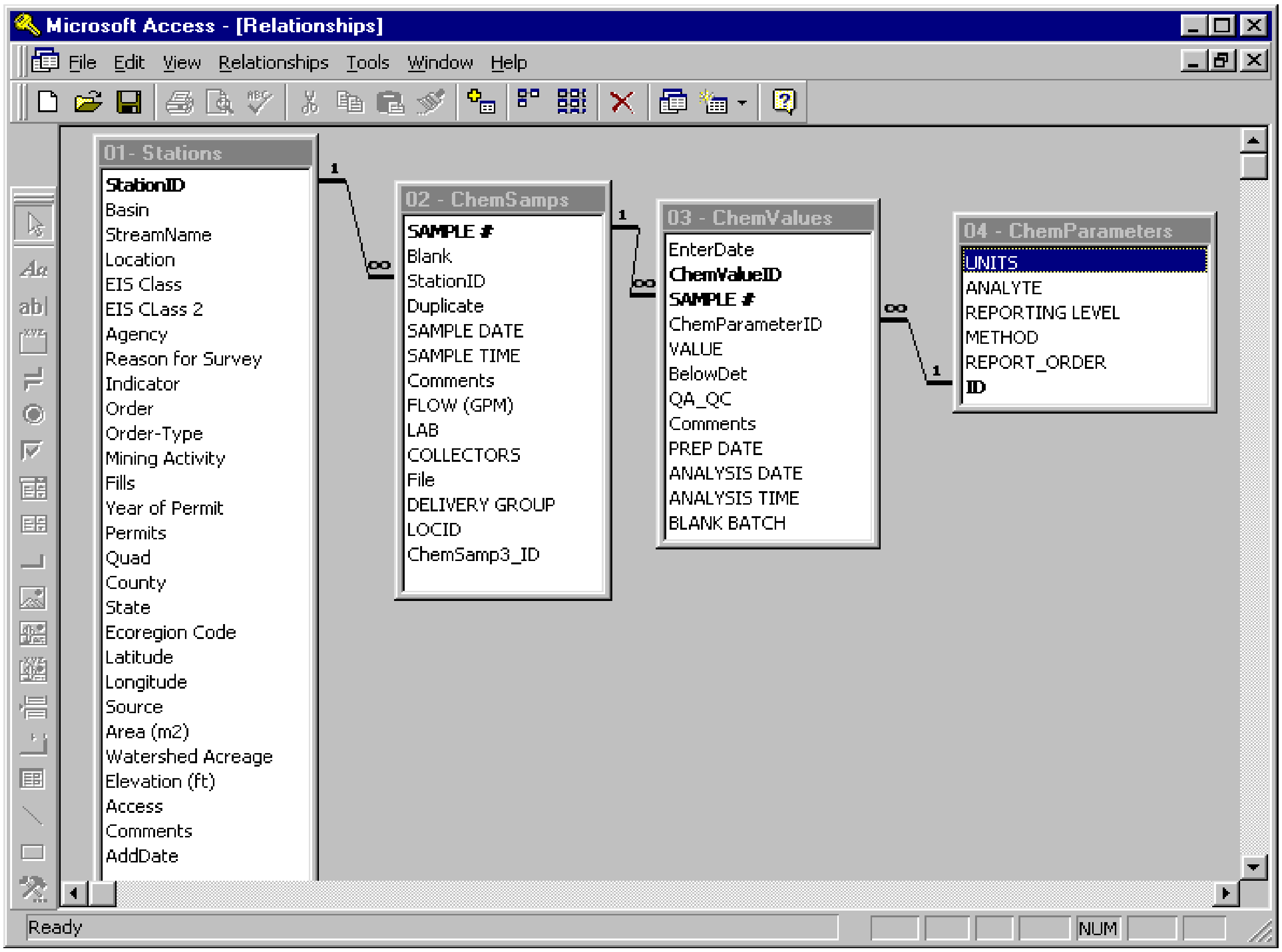
4.4 Database of the Results

The evaluation of the large amount of data collected during this study has been facilitated by compiling it in an electronic database. Much of the results of analyses from both laboratories were provided to EPA in an electronic format. These data were merged into a single database. This process included standardizing field names, chemical parameter names, and units of measurement. The mountaintop mining chemistry database was established using the Microsoft Access97® relational database. It is included in this report as APPENDIX 3. The database is compatible with most other database software. It can be linked to other applications such as ArcView®, ArcInfo®, or USEPA's STORET. Figure 2 illustrates how the database is organized. The chemistry database contains a collection of four tables that are linked by one or more fields in order to facilitate data analysis. Information regarding each sampling site is listed in the table *01-Stations*. Information about each sample is in the table *02-ChemSamps*. Laboratory results for each sample are stored in the table *03-ChemValues.* Information about the chemical parameters is in the table *04-ChemParameters* This vast amount of information was separated into four tables to reduce repetition within the database.

At least one field in each of the tables is the primary key for the table which functions as a unique identifier for the information stored in that table. Primary keys are used to link the tables to one another using one-to-many relationships. For example, the field *StationID* is the primary key for table *01 - Stations* and is used to link to table *02 - ChemSamps*. *StationID* is not duplicated in table *01 - Stations*, but it is duplicated in table *02-ChemSamps* because stations were sampled multiple times in this study.

Figure 2.
Organization of Database

Not all the chemical analyses were provided in electronic form from the laboratories. Four



months of lab chemistry data and field chemical parameters for all of the samples were only available in paper form. This data was entered into the database by EPA staff using a set of data entry forms they created to simplify and standardize the data entry process. Staff at the Wheeling office completed an independent check of 100% of the data entry performed at Wheeling and also checked the remainder of the values in the database against the paper copies of laboratory reports and field sheets. Additional checks on the quality of the data and data entry were made using queries of the database. A request to retrieve or manipulate data from the database is called a query. Queries can filter and summarize data from one or more of the database tables by setting specific criteria and then displaying the results in tabular form. For example, queries can select specific data such as finding all of the samples where a particular value is greater than a specified water quality criteria. They can also perform functions such as calculating hardness from total calcium and total magnesium values. Range checks were performed using queries for each parameter. They provided an extra indication of the accuracy of the data entry since outliers were again verified using the original lab reports. The range checks were useful because they indicated a group of samples where the values for dissolved aluminum, iron and manganese were reported by the laboratory using incorrect units. This problem was then resolved with a letter from the laboratory correcting the errors. An examination of the range of the data also highlighted the importance of considering the values reported for blank samples and highlighted temporal and/or laboratory differences for several chemical parameters.

As a result of QA/QC verification and validation procedures, additional information was added to the original database preserving the original data, but allowing for a record of QA/QC evaluations. The *03-ChemValues* table contains a *QA_QC* field for recording data “flags”. A *“R”* was placed in the QA field for chemistry values that were rejected in the QA/QC data review. Likewise a “*B”* was added to the QA field when the laboratory results for blanks was greater than or equal to 10% of the sample results. A *“RWHL*” was entered in the *QA_QC* field where the report writers identified problems with the data such as when the value for dissolved organic carbon was greater than the value for total organic carbon or when a note from the chemist indicated acid appeared to have been added to the wrong sample container. Some other values were rejected based on the field sheet notes of problems encountered at the time of sampling. For example, the field sheet for one sample noted they only acidified bottles 2 & 6. These field sampling problems were flagged *“RWHL”* and the appropriate values were rejected from the data evaluation.

5. EVALUATION AND DISCUSSION OF RESULTS

Several methods of evaluating the data were undertaken in seeking to characterize and compare conditions in streams below mountaintop removal / valley fill mining operations. This evaluation was made more complicated by several factors including variations in the quality of the data. The precision of sampling results varied with each parameter as well as with laboratory over the duration of the study. The results of the duplicate samples and blank samples are used to assess the precision of sample results and better evaluate the true impact. This evaluation was facilitated by storing the data in an electronic database which is described first in this evaluation and discussion.

The initial evaluation seeks to identify **parameters likely to be impacted by MTM/VF mining.** The average water quality at all Filled sites is compared to the water quality at all Unmined sites sampled during this study. The parameters most altered are then examined for all categories of sites for the entire data set to evaluate mining impacts on each parameter. Variations in data quality are evaluated using the duplicate sample results. Additional insight is provided through calculation of a value called "Yield,"an idea taken from a USGS publication (Sams & Beer 2000, page 10). Yield rates are calculated by dividing loading values by the drainage area.

The second approach in this evaluation is to identify the samples and sites which **exceeded West Virginia's stream water quality criteria**. Sites which have multiple violations are described and characterized.

Finally, the eight parameters which had **little or no detectable concentrations** in any samples are listed and briefly discussed.

5.1 Parameters Likely To Be Impacted By MTM/VF Mining

5.1.a Filled Sites vs Unmined Sites

The median concentration from all Filled sites was compared to the median concentration from all Unmined sites to identify which parameters were most likely to be impacted by MTM/VF mining. The ratio of Mined to Unmined was used to prioritize the discussion and evaluation of the data from all categories of sites. Only data from the second laboratory was used in this comparison since there were data quality differences between the two laboratories. Table 6 lists the median values for all Filled site data and all Unmined site data as well as the ratios for each parameter. There are 16 parameters with a ratio greater than 1.0 and each will be discussed individually beginning with sulfate. The 25 remaining parameters will also be discussed but they may be discussed in groups of parameters or in later sections of this report.

Table 6. Median Values at All Filled vs All Unmined Sites - Lab 2 Only

Parameter	*Median Unmined**	*Median Filled**	*Ratio Filled/Unmined*	*Det. Limit @ Lab 2**
Sulfate	12.55	523.5	**41.7**	5
Calcium	4.875	104	**21.3**	0.1
Magnesium	4.095	86.7	**21.2**	0.5
Hardness	29.05	617	**21.2**	3.31
Solids, Dissolved	50.5	847	**16.8**	5
Manganese, Total	0.005	0.04395	**8.8**	0.01
Conductivity, Field (uS/cm)	66.4	585	**8.8**	N/A
Selenium	0.0015	0.01168	**7.8**	0.003
Alkalinity	20	149.5	**7.5**	5
Potassium	1.58	8.07	**5.1**	0.75
Sodium	1.43	4.46	**3.1**	0.5
Manganese, Dissolved	0.005	0.01035	**2.1**	0.01
Chloride	2.5	4.5	**1.8**	5
Acidity	2.5	4.25	**1.7**	2
Nitrate/Nitrite (N)	0.81	0.95	**1.2**	0.1
pH, Field (std)	6.78	7.77	**1.1**	N/A
Acidity, Hot	2.5	2.5	1.0	5
Aluminum, Dissolved	0.050	0.050	1.0	0.1
Antimony	0.0025	0.0025	1.0	0.005
Arsenic	0.001	0.001	1.0	0.002
Beryllium	0.0005	0.0005	1.0	0.001
Cadmium	0.0005	0.0005	1.0	0.001
Chromium	0.0025	0.0025	1.0	0.005
Cobalt	0.0025	0.0025	1.0	0.005
Copper	0.0025	0.0025	1.0	0.005
Lead	0.001	0.001	1.0	0.002
Mercury	0.0001	0.0001	1.0	0.0002
Nickel	0.010	0.010	1.0	0.02
Organic Carbon, Total	1.35	1.4	1.0	1
Phosphorous	0.05	0.05	1.0	0.1
Silver	0.005	0.005	1.0	0.01
Thallium	0.001	0.001	1.0	0.002
Vanadium	0.005	0.005	1.0	0.01
Barium	0.02885	0.02465	0.9	0.02
Dissolved Oxygen, Field	13.6	11.045	0.8	N/A
Organic Carbon, Dissolved	2.45	1.95	0.8	1
Solids, Suspended	5.75	4.25	0.7	5
Iron, Total	0.417	0.1935	0.5	0.1
Iron, Dissolved	0.220	0.096	0.4	0.1
Zinc	0.006	0.0025	0.4	0.005
Aluminum, Total	0.147	0.050	0.3	0.1

* Concentrations are in mg/L unless noted.

5.2 Sulfate Data

Although there is no stream criterion for sulfate in West Virginia to protect aquatic life, several groups have looked at the impacts of sulfate on other water uses. The adverse effects of high concentrations of aluminum in water supplies were noted in EPA's "Blue Book 1972." Their recommendation was:

> On the basis of taste and laxative effects and because the defined treatment process does not remove sulfates, it is recommended that sulfate in public water sources not exceed 250 mg/l where sources with lower sulfate concentrations are or can be made available. (Rolich et al 1972, page 89)

This recommendation was set to protect human health at water supplies using surface waters as a source. Additional research should be conducted to investigate the effects of sulfates on aquatic life. Regarding the impact on aquatic life, the California State Water Resources Control Board publication *Water Quality Criteria* 1963 edition states:

> In U.S. waters that support good game fish, 5 percent of the waters contain less than 11 mg/l of sulfates, 50 percent less than 32 mg/l, and 95 percent less than 90 mg/l. Experience indicates that water containing less than 0.5 mg/l sulfate will not support growth of algae. (McKee et al 1963, page 276)

MTM/VF permit writers in West Virginia recognize sulfates as a significant indicator of mining activity. Their Cumulative Hydrologic Impact Assessment (CHIA) report for the Twentymile Creek watershed states:

> The data indicate that the sulfate concentrations are increased with mining. Sulfates are endemic to mining areas and are indicators of mining in a watershed. A rule of thumb can be observed from the water quality data researched for this CHIA. This rule is (A) below 20 mg/l there is no mining in the watershed (B) between 20 and 30 mg/l there has been very little or no impact from mining in a watershed (C) from 30 to 100 mg/l there has been some impact from mining (D) above 100 mg/l there has been certain impact from mining. (West Virginia Department of Environmental Protection, CHIA for Twentymile Creek, pages not numbered)

5.2.a Sulfate Concentration in Stream Samples

The concentration of sulfate at each site varied with time during this study. The values for each sample from all sites have been plotted against time in Figure SO_4-1. Each category of site has been plotted with a different symbol so the variation of concentrations classes of sites can be evaluated. The detection limit was 10 mg/L at the first laboratory and 5 mg/L at the second laboratory.

The sulfate concentrations at the Unmined sites fit the rule of thumb for unmined watersheds set by the CHIA report writers and were well below the recommended drinking water criterion of 250 mg/l. The median concentration for all Unmined sites was only 14.25 mg/L. The US Geological Survey report Water Quality in the Allegheny and Monongahela River Basins, Circular 1202", published in 2000 indicates the regional background concentration of sulfate in unmined watersheds in the northern portion of the Appalachian coal field averages about 21 mg/l (Anderson et al 2000, page 20), which is similar to the concentrations at Unmined sites in this study.

Many samples from the categories Filled and Mined had sulfate values exceeding the recommended drinking water standard of 250 mg/L. Especially noteworthy are the values for the samples from site MT-24, a yellow diamond symbol in Figure SO_4-1. The concentrations ranged from 800 to 2,300 mg/L and are consistently higher than the concentration at all other types of sites. This site is not a stream but a flow diversion ditch at an MTM/VF mine. Obviously the site is a source of sulfate to the stream below. The sites in the category Filled comprise the majority of the higher concentrations.

Figure SO_4-1. Sulfate Concentrations for All Sites vs. Date

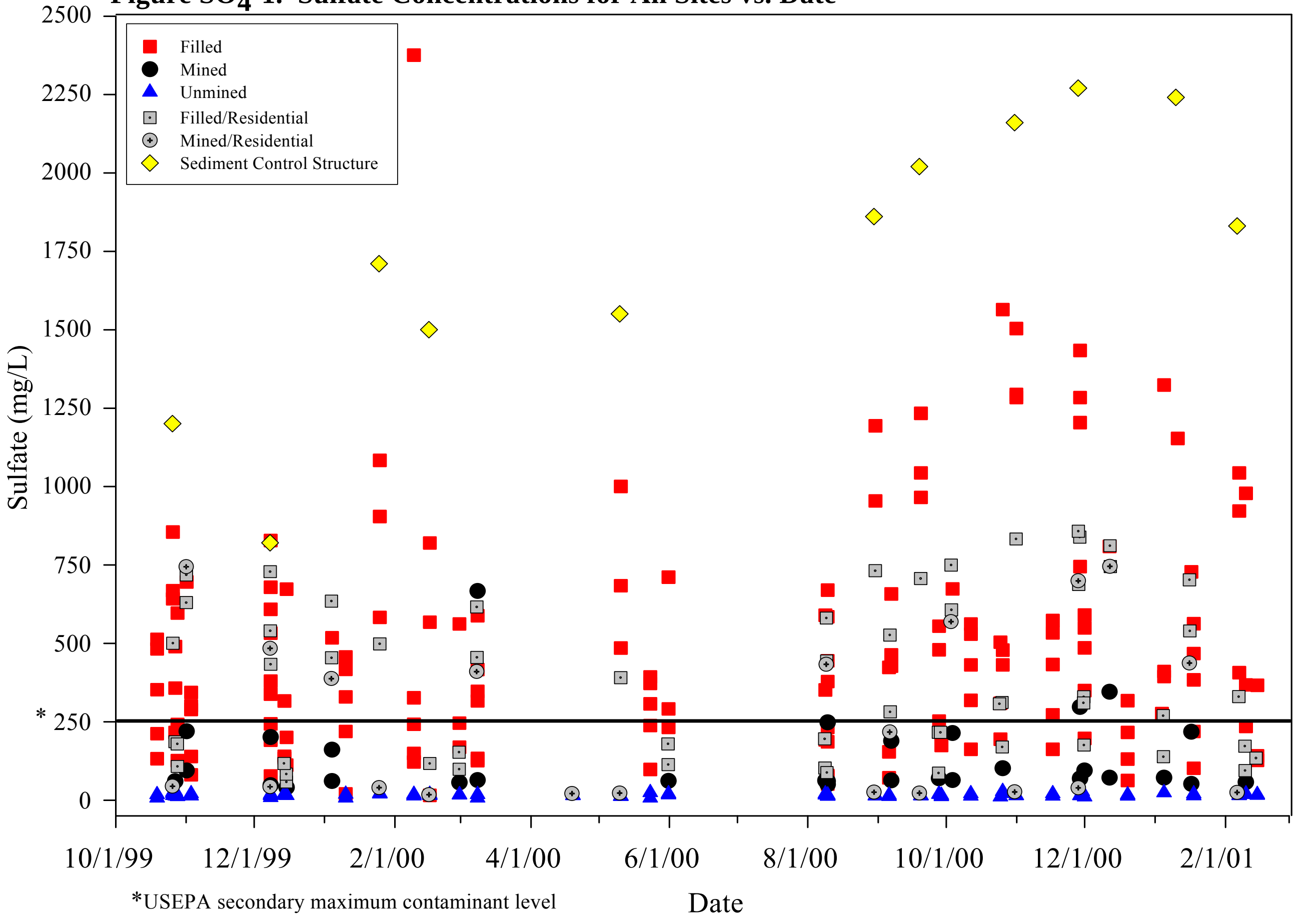


Table SO_4-1 lists a summary of the 172 samples which exceed the Secondary Maximum Contaminant Level of 250 mg/L for Sulfate. Roughly 45 % of the samples which passed the QA/QC review exceeded the sulfate criterion but none came from sites in the category Unmined. There are 110 samples from the category Filled, and another 37 samples from the category Filled/Residences. There are 4 samples at Mined sites and another 10 from the category Mined/Residences. There were 11 samples from the diversion ditch exceeding the criterion. The sites where the sulfate concentration was high were scattered across the study area in areas where coal mining has occurred.

Table SO_4-1. Number of Samples Exceeding the Secondary Maximum Contaminant Level of 250 mg/L for Sulfate

Station ID	EIS Class	No. Samples > 250 mg/L
MT-14	Filled	10 of 11
MT-15	Filled	10 of 10
MT-18	Filled	11 of 11
MT-25B	Filled	7 of 10
MT-32	Filled	4 of 10
MT/34B	Filled	10 of 10
MT-52	Filled	3 of 8
MT-57B	Filled	6 of 7
MT-64	Filled	11 of 11
MT-87	Filled	3 of 13
MT-98	Filled	13 of 13
MT-103	Filled	12 of 13
MT-104	Filled	10 of 13
MT-23	Filled/Residences	10 of 11
MT-48	Filled/residences	3 of 10
MT-55	Filled/Residences	2 of 8
MT-62	Filled/Residences	11 of 11
MT-75	Filled/Residences	11 of 11
MT-79	Mined	4 of 11
MT-69	Mined/Residences	10 of 11
MT-24	MTM/VF Diversion Ditch	11 of 11

5.2.b QA Samples for Sulfate

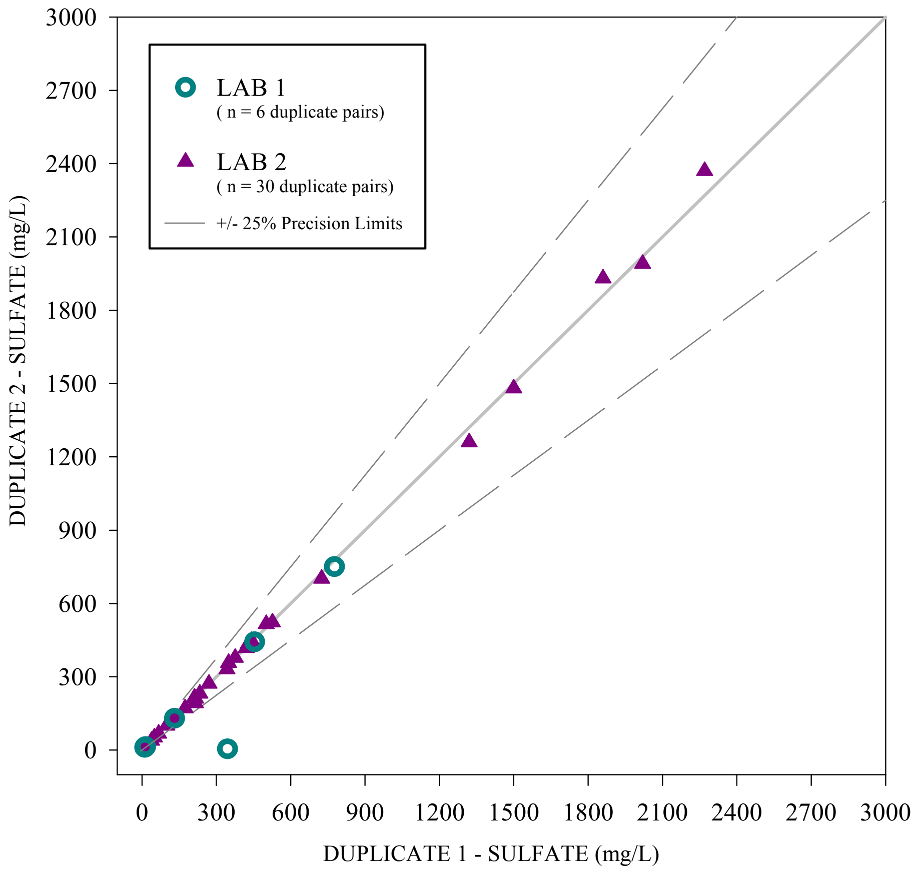
Evaluation of the results of duplicate samples indicate the values for sulfate are generally precise. The QA/QC review of the data checked for accuracy. The sulfate data remaining are suitable for evaluating the impacts to stream chemistry resulting from MTM/VF mining. The Relative Percent Difference (RPD) values for the 44 sets of field duplicate samples are listed in Table SO_4-2.

Table SO_4-2. RPD for Field Duplicates for Sulfate

Station ID	Sample Date	Laboratory	RPD
MT104	3/8/00	LAB 1	194
MT62	3/8/00	LAB 1	3
MT86	3/8/00	LAB 1	1
MT02	4/19/00	LAB 1	1
MT02	5/10/00	LAB 1	1
MT75	6/13/00	LAB 1	3
MT25B	8/8/00	LAB 2	2
MT104	8/9/00	LAB 2	1
MT52	8/9/00	LAB 2	5
MT62	8/9/00	LAB 2	1
MT24	8/30/00	LAB 2	4
MT98	9/5/00	LAB 2	1
MT75	9/6/00	LAB 2	1
MT24	9/19/00	LAB 2	1
MT48	9/27/00	LAB 2	11
MT51	9/28/00	LAB 2	0
MT79	10/3/00	LAB 2	1
MT95	10/11/00	LAB 2	1
MT57B	10/24/00	LAB 2	3
MT25B	10/25/00	LAB 2	1
MT15	10/31/00	LAB 2	1
MT87	11/16/00	LAB 2	1
MT24	11/28/00	LAB 2	4
MT81	11/28/00	LAB 2	1
MT40	11/30/00	LAB 2	2
MT50	11/30/00	LAB 2	2
MT79	12/11/00	LAB 2	4
MT91	12/19/00	LAB 2	0
MT55	1/3/01	LAB 2	2
MT34B	1/4/01	LAB 2	5
MT01	1/10/01	LAB 2	1
MT64	1/16/01	LAB 2	3
MT86	1/17/01	LAB 2	0
MT02	2/6/01	LAB 2	1
MT32	2/9/01	LAB 2	1
MT55	2/14/01	LAB 2	2

The highest RPD for the duplicates was 11 and many values were 1. This indicates the data for sulfate was generally precise throughout the study. The results of duplicate samples are also presented in Figure SO_4-2, Comparison of Duplicate Samples - Sulfate Concentration. In this graph, duplicate sets of sample results are plotted with one value being plotted on the x-axis and the other plotted on the y-axis. If a set of duplicate samples had exactly the same concentration value, the point would fall on a line from zero/zero to 3000/3000. A general limit on precision of plus or minus 25% was used in this study. This precision limit is also shown on the Figure to illustrate if a set of duplicate samples are out of normal precision limits or "out of control." In addition, the values from the two laboratories are plotted with different symbols to determine if there is a difference in precision between the data from the two parts of the study. There were nine sets of duplicate samples rejected in the QA/QC review of laboratory results, and all were during the early part of the study at laboratory 1. No duplicates were rejected in data from the second laboratory.

Figure SO_4-2. Comparison of Duplicate Samples - Sulfate Concentrations



The agreement in results for each set of duplicates is evident. Duplicate samples run at the second laboratory had a wider range of concentrations but were still quite precise.

The concentration of sulfates in the 80 blank samples should have been below the detection limit. There was only one sample with a detectable concentration of sulfate and it was at the first laboratory. Of the 80 blank samples, there were 28 pairs of duplicate blank samples and all were below the detection limit in the laboratory indicating no detectable contamination occurred from sample handling in the field or the laboratory. The quality of the data for sulfate is good.

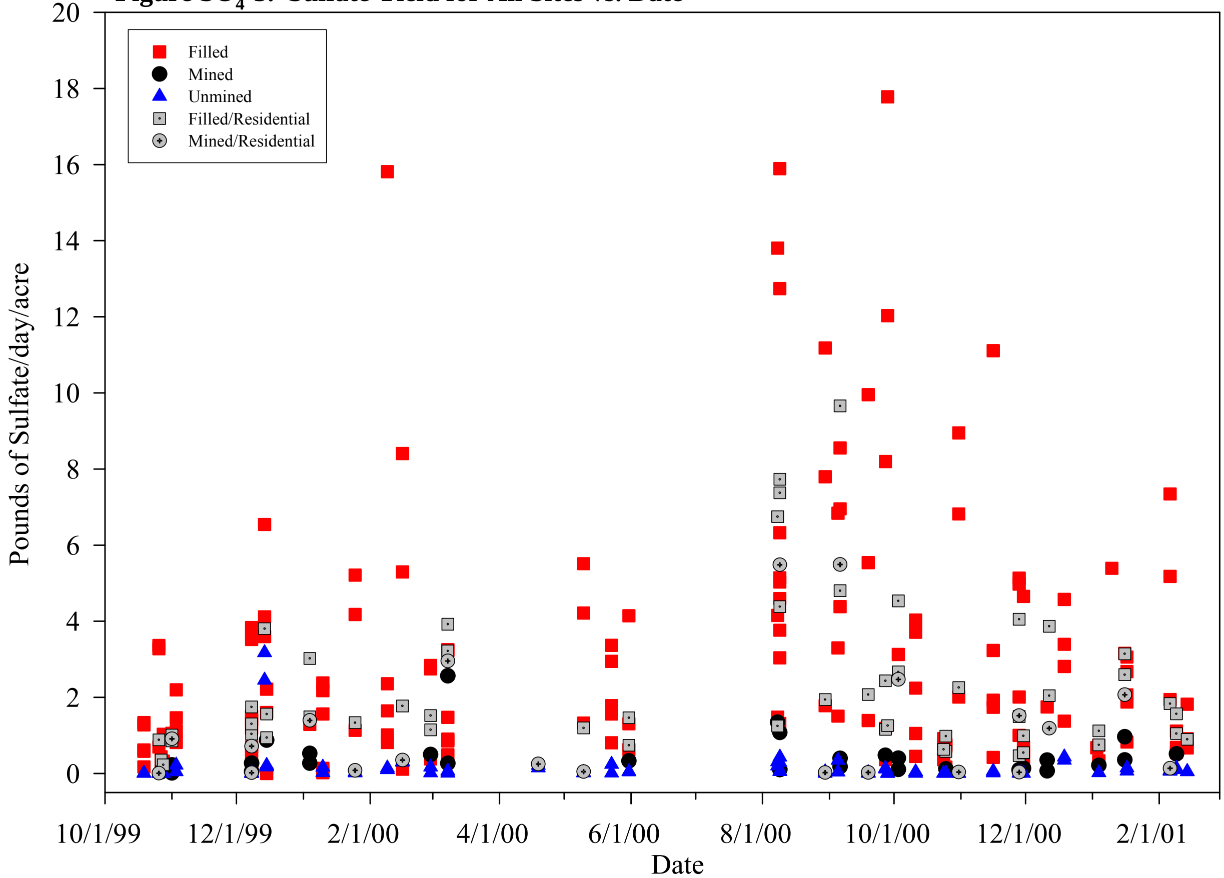
5.2.c Sulfate Yield

Sulfate has long been considered a good indicator of the presence of coal mine drainage in streams in Appalachia. The relationship between coal mining and sulfate in streams is the focus of the US Geological Survey Water-Resources Investigations Report 99-4208 (Sams & Beer, 2000). The report notes that sulfate is an excellent indicator of mine drainage because the sulfate ion is very soluble and chemically stable at the pH levels normally encountered in streams, and the treatment of mine drainage to remove metals and neutralize acidity has little or no effect on sulfate concentration. The authors calculated the annual discharge of sulfate at selected stream monitoring points and divided that loading by the drainage area above the monitoring point to determine “Sulfate Yield” in tons per year per square mile. They used these Sulfate Yield rates to rank stream degradation attributable to mining. A similar approach has been used in this report to evaluate the impacts of mining on the streams.

Sulfate Yield was calculated for each sampling event at each site. The first step was to calculate the instantaneous sulfate load for each sample event by multiplying the sulfate concentration (mg/L) times the instantaneous flow rate (cubic feet per second) times the conversion factor (5.39) to get a load in pounds per day. The Sulfate Yield was then determined by dividing the instantaneous sulfate load by the drainage area above that site. The Sulfate Yield in this report is measured in pounds of sulfate per day per acre. These Sulfate Yield values vary at each site with each sampling event. They also vary with the categories of sites being evaluated in this study - Unmined, Mined, Filled, Filled with Residences, and Mined with Residences. No Sulfate Yield values were calculated for site MT- 24 since there is no accurate data on the area now draining to the site. Mountaintop mining has changed the original drainage patterns and there is no accurate map of the new watershed boundary. The variations in Sulfate Yield can be plotted against time to compare categories of sites. Figure SO_4-3 is a graph of Sulfate Yield rates for all sites vs date.

The production of sulfate per acre at sites in the “Filled” category is much higher than at “Unmined” sites. The highest yields are consistently from “Filled” sites and range from 0 to over 14 pounds per acre per day. Sulfate Yield rates at Unmined sites are consistently less than one pound per acre per day. There are two samples collected in December 1999 at Unmined sites with yield rates greater than 2 pounds per day per acre. Those samples are from sites MT-50 and MT-51. The field sheet includes the note “Heavy precipitation in the last 24 hours,” which would explain the higher yield rate values for these Unmined sites.

Figure SO_4-3. Sulfate Yield for All Sites vs. Date



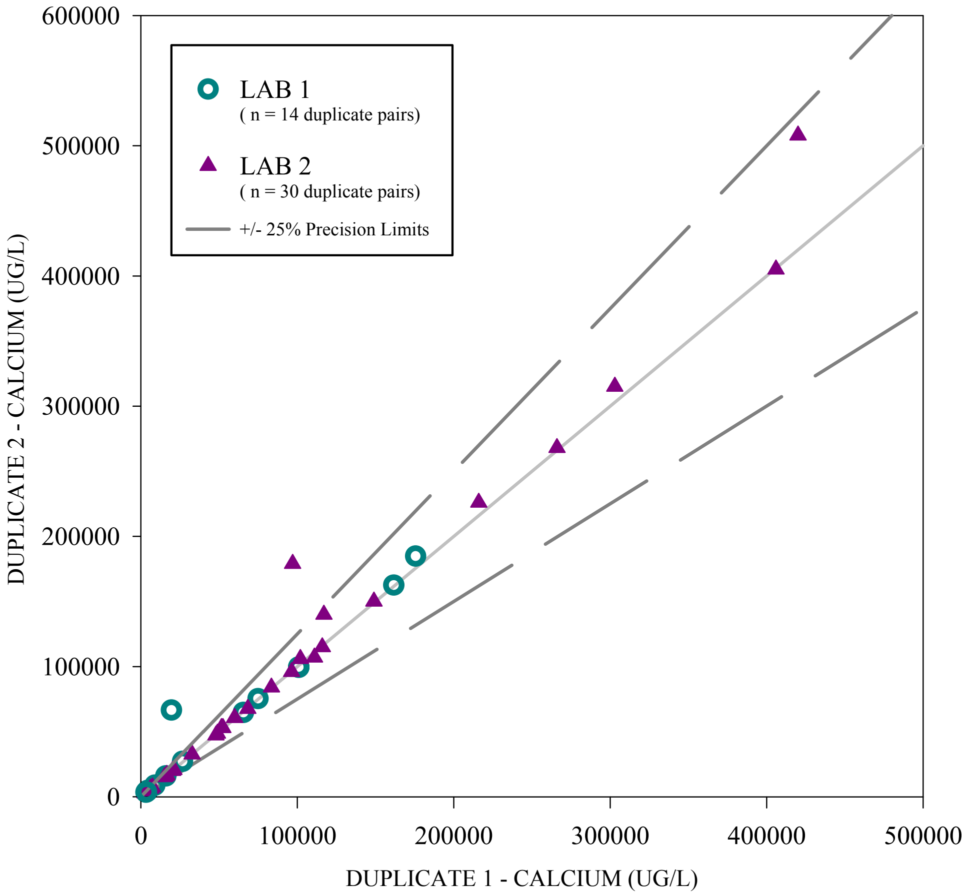
The Sulfate Yield rates described in the US Geological Survey Water-Resources Investigations Report 99-4208 (Sams & Beer, 2000) were measured in tons per year per square mile. The Yield rate for two unmined watersheds in this USGS study was calculated to be 24 tons in one watershed and 25 tons per year per square mile in another. (Sams et al 2000, page 9) This is equivalent to about 0.2 pounds per day per acre. Mined watersheds produced up to 580 tons per year per square mile (about 5 pounds per day per acre). These sulfate yield rates are for drainage areas that are many miles away from the region of mountaintop mining and have different geology. The Allegheny and Monongahela River watersheds are dominated by high sulfur coals while low sulfur coals dominate the geology of the region of mountaintop mining. Even so, the values for Sulfate Yield in the northern high sulfur region are similar to those in the study area. Unmined watersheds produce less than a pound of sulfate per day per acre and heavily mined watersheds can produce 5 pounds per day per acre or more. Sulfate is an excellent indicator of coal mining activity throughout the northern Appalachian coal field. MTM/VF mining operations increase the concentration of sulfate in streams draining the mining sites.

5.3 Calcium Data

Calcium is a significant part of hardness, but like magnesium, it does not have water quality limits. According to the California State Water Resources Control Board's *Water Quality Criteria*, calcium salts and calcium ions are among the most commonly encountered substances in water. They result from the leaching of soil and other natural sources. Calcium is an essential element for plants and animals. Concerning the impacts to fish and other aquatic life, the report notes:

> Calcium in water reduces the toxicity of many chemical compounds to fish and other aquatic fauna. ..... According to a reference cited by Hart et al., of the U.S. water supporting a good mix of fish fauna, ordinarily about 5 percent have less than 15 mg/l of calcium; 50 percent have less than 28 mg/l; and 95 percent have less than 52 mg/l.

Figure Ca-1. Comparison of Duplicate Samples - Calcium



The results of duplicate samples for calcium are shown in Figure Ca-1. The detection limit was 100 ug/L. The precision was good for both laboratories, and again there were higher values from the second laboratory. There were 13 blank samples of the 80 collected which had detectable concentrations of calcium. All were collected in the first half of this study and analyzed at the first laboratory. Further discussion of the calcium concentrations from this study will focus on the significant contribution of calcium to hardness.

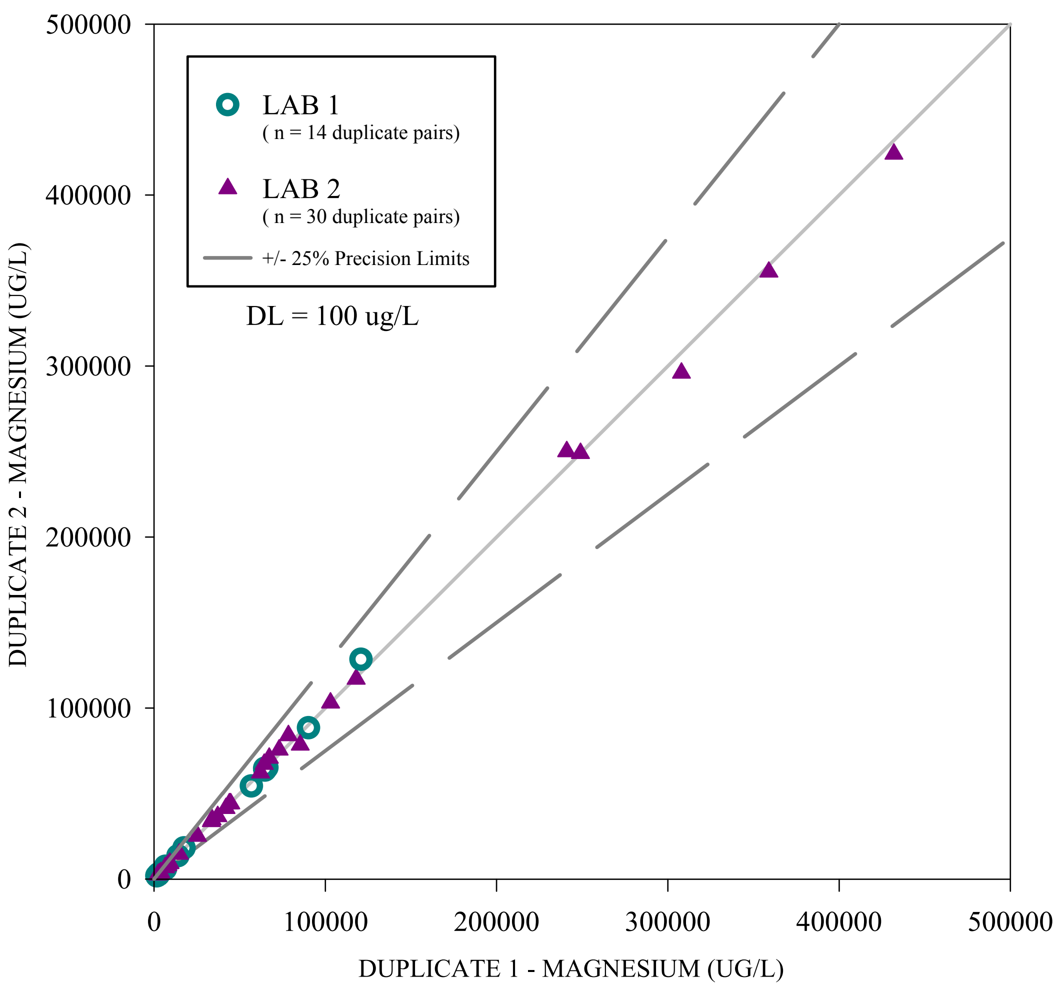
5.4 Magnesium Data

According to the California State Water Resources Control Board's *Water Quality Criteria*, magnesium constitutes about 2.1 % of the crust of the earth being widely distributed in ores and minerals. The salts of magnesium are very soluble. Magnesium is an essential element for plants and animals. Magnesium is considered relatively non-toxic to humans and not a health hazard because, before toxic concentrations are reached in water, the taste becomes quite unpleasant. Concerning the impacts to fish and other aquatic life, the report notes:

> Hart et al. cite a report that among U.S. waters supporting a good fish fauna, ordinarily 5 percent have less than 3.5 mg/L of magnesium; 50 percent have less than 7 mg/L; and 95 percent have less than 14 mg/L.

The results of duplicate samples are plotted in Figure Mg-1. The detection limit was 100 ug/L. None of the laboratory values for magnesium in this study were rejected in the data quality revi
ews.

Figure Mg-1. Comparison of Duplicate Samples - Magnesium



The results of duplicate samples are very precise across a wide range of concentrations. The values at the second laboratory were higher than those at the first. Ten percent of the eighty blank samples had detectable concentrations of magnesium. All of these contaminated blank samples were collected in the first half of the study. The detection limit for magnesium is 100 ug/L which is 3% of the median value detected at Unmined sites so the increase is well above the minimum detectable values. Further discussion of the magnesium concentrations from this study will focus on the significant contribution of magnesium to hardness.

5.5 Total Hardness Data

According to the California State Water Resources Control Board's *Water Quality Criteria*, the term "Hardness" refers to the soap-neutralizing power of water. Any substance that will form an insoluble curd with soap causes hardness. Hardness is attributable principally to calcium and magnesium ions but other metals can increase hardness. Indeed the standard method (Method 2340 B) for calculating hardness is determined using only the concentrations of calcium and magnesium. The equation is:

Hardness in mg/L = 2.497 (Calcium in mg/L) + 4.118 (Magnesium in mg/L)

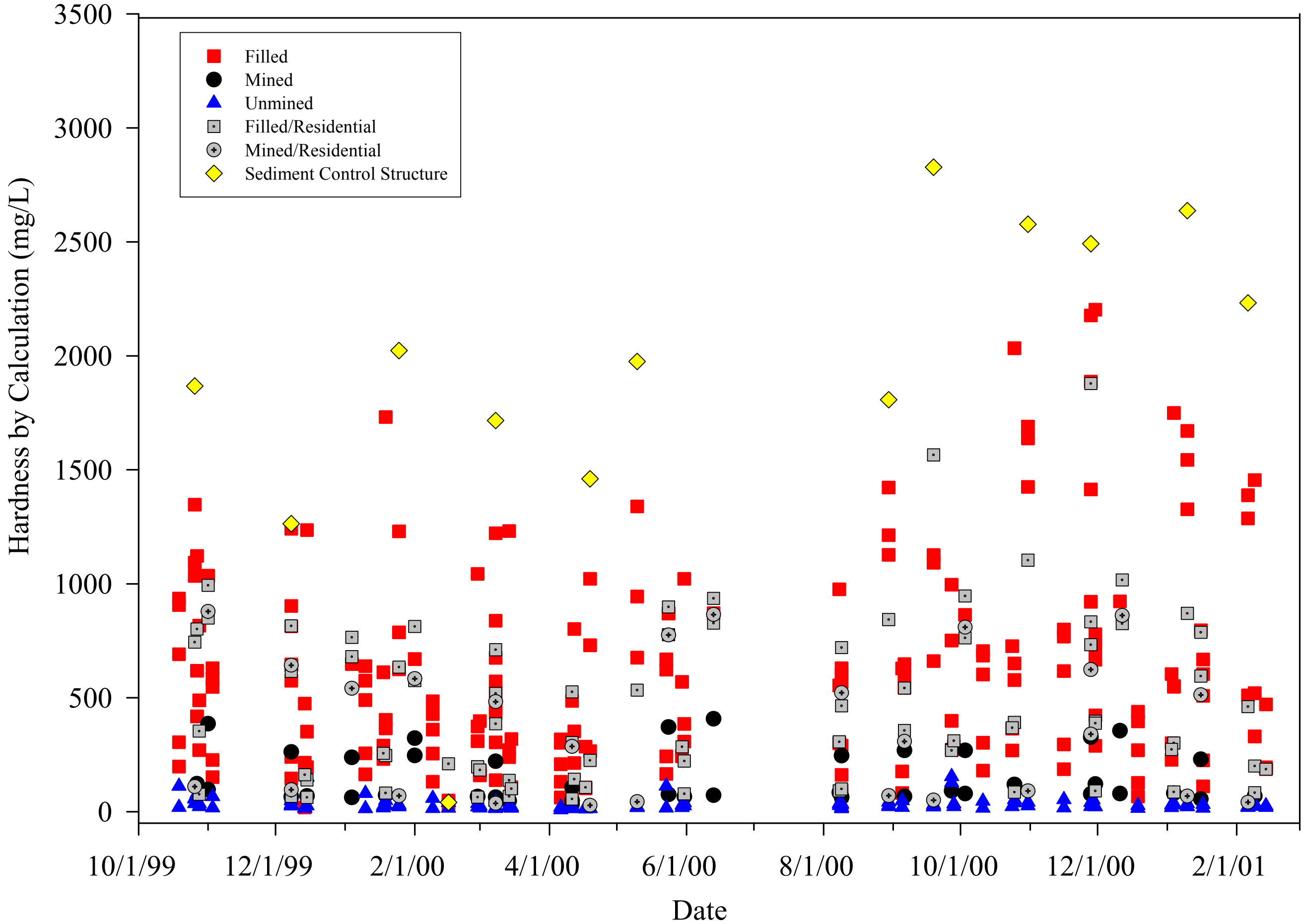
The hardness values were calculated for each sample and used in this evaluation of hardness concentration. Acceptable levels of hardness in drinking waters vary with consumer preference and "good drinking water" can have a maximum hardness from 140 mg/l to 270 mg/l. Regarding the impact of hardness on aquatic life, this reference states, "Soft water solutions increase the sensitivity of fish to toxic metals; in hard waters toxic metals may be less dangerous."

Several stream water quality criteria for toxic metals have been established with a limit that varies with the hardness in the stream. The harder the water the more of the toxic metal can be present without causing toxicity. West Virginia has set water quality limits on toxic metals to protect aquatic life in streams in this study area. These limits are calculated from equations which use the hardness concentration to calculate the maximum allowable concentration of the metal. Limits have been set for the following dissolved metals: cadmium, copper, lead, nickel, silver, and zinc. Hardness is an acceptable contaminant for most water uses in low concentrations.

5.5.a Hardness Concentration in Stream Samples

The concentration of hardness at each site varied with time during this study. The values for each sample from all sites have been calculated and plotted against time in Figure H-1. Each category of site has been plotted with a different symbol so the variations between categories can be evaluated. Unmined sites consistently have the lowest concentration of hardness while the Sediment Control Structure (MT-24) has the highest concentrations. All types of sites which have mining activity upstream also have elevated concentrations of hardness, with the Filled category sites generally being higher.

Figure H-1. Hardness Concentration for All Sites vs. Date



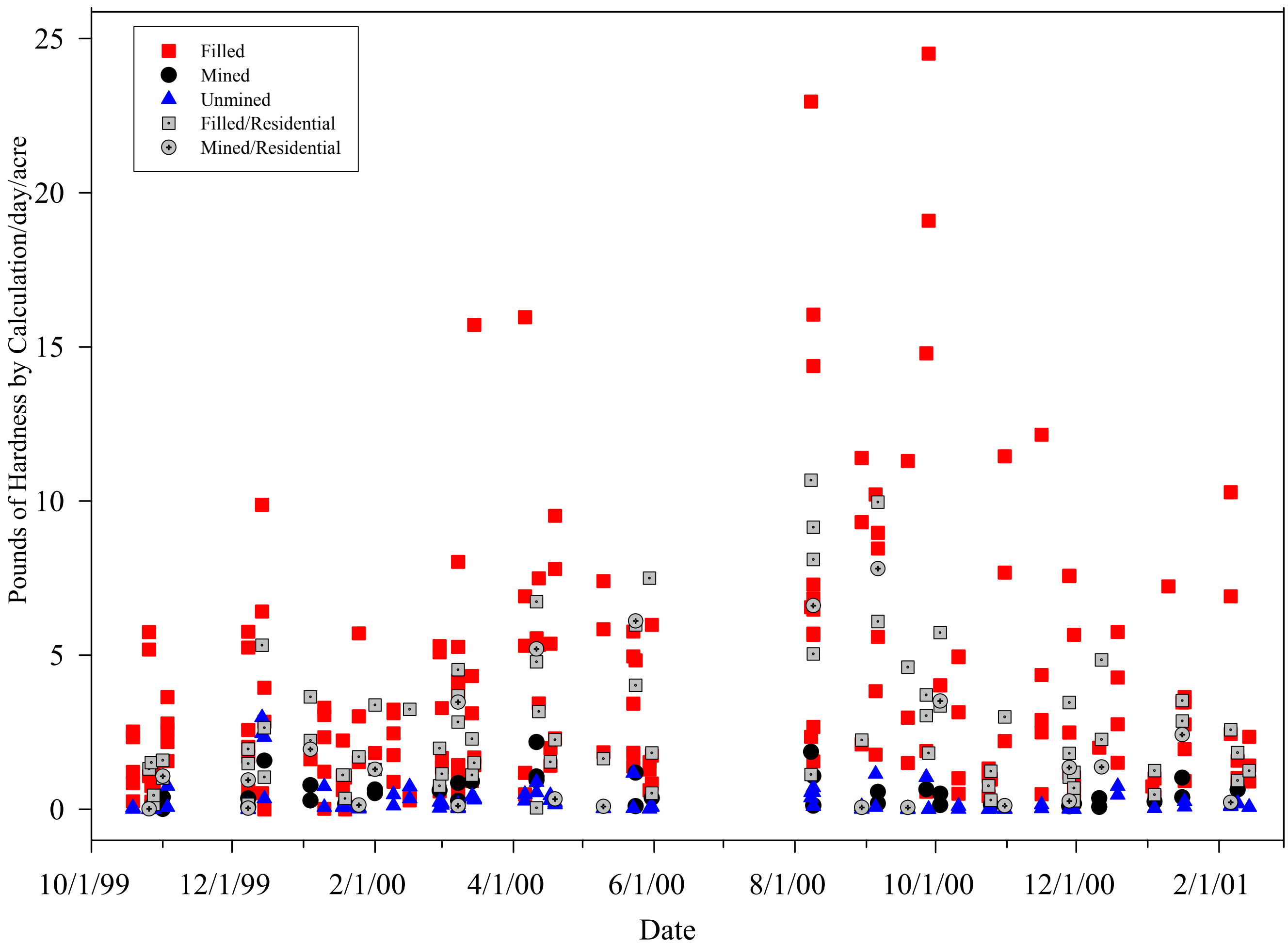
5.5.b QA Samples for Hardness

Hardness values were calculated from the concentration of calcium and magnesium. The QA samples for those parameters have been presented so there is no need for additional discussion.

5.5.c Hardness Yield

The Yield of hardness in pounds per day per acre for each sample is presented in Figure H-2. The Yield for Unmined sites is generally less than one pound per day per acre while the Yield for Filled sites is generally above two pounds per day per acre with some values nearly 25 pounds per day per acre. Higher Yields are also evident at Filled/Residential and Mined/Residential sites. There appear to be higher Yield values in the second half of the study. There are also two samples collected in December 1999 at two Unmined sites with yield rates above 2 pounds per day per acre. A note on the field sheet states “Heavy rainfall for the previous 24 hours,” which would account for these higher yield rates. The data from both laboratories indicate Filled sites have elevated values for Hardness Yield.

Figure H-2. Hardness Yield for All Sites vs. Date



5.6 Total Dissolved Solids Data

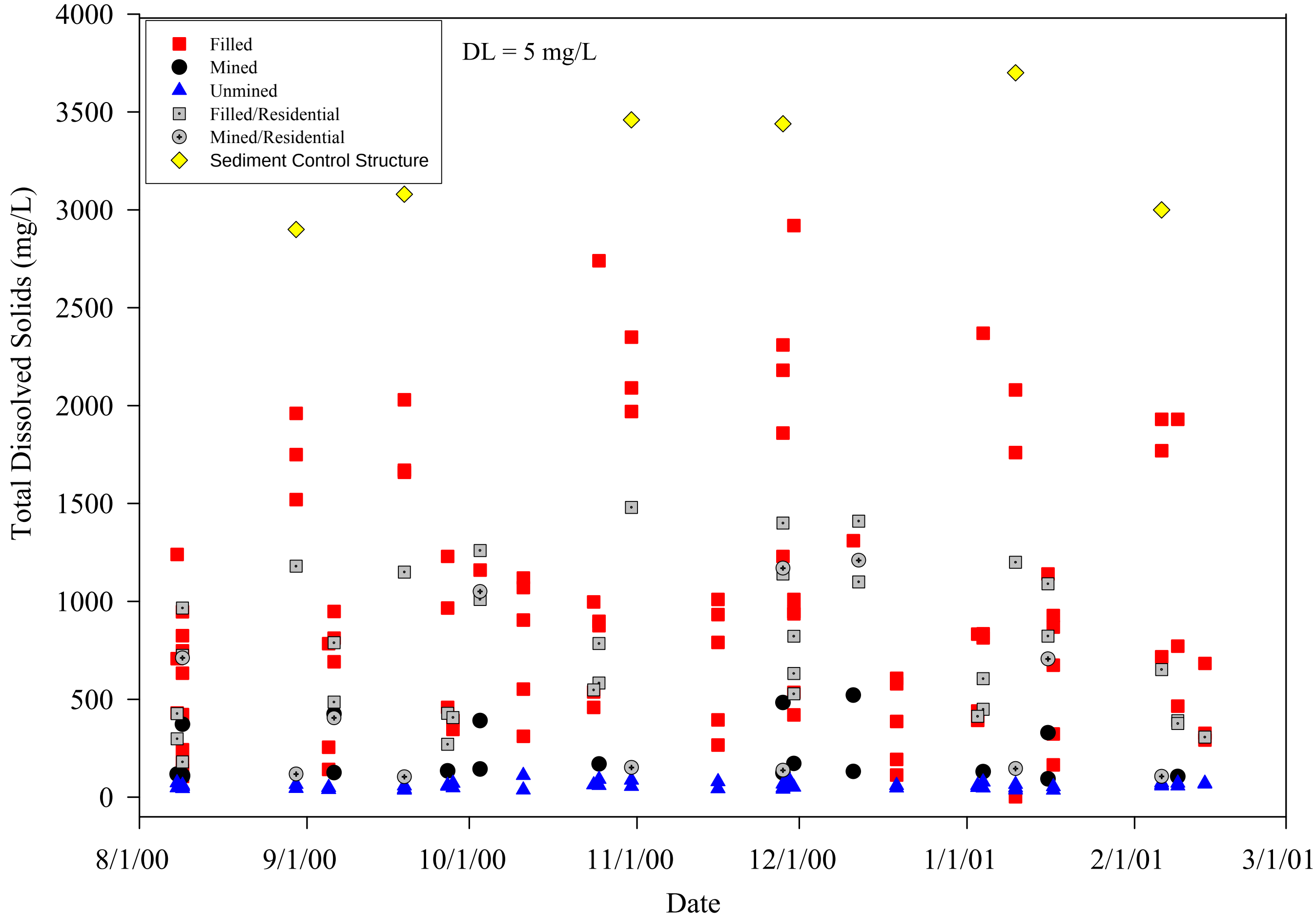
In natural waters the dissolved solids are various minerals in their ionic form including carbonates, bicarbonates, chlorides, sulfates, phosphates, and nitrates of various metals. Since dissolved solids are often a diverse mix of various salts, the effect on use of the water can be equally diverse. For drinking water, the U.S. Public Health Service in 1962 recommended that the total dissolved solids should not exceed 500 mg/l if more suitable supplies are or can be made available. Regarding protection of fish and aquatic life, the California State Water Resources Control Board's *Water Quality Criteria* states:

> It has been reported that among inland waters in the United States supporting a good mixed fish fauna, about 5 percent have a dissolved solids concentration under 72 mg/L; about 50 percent under 169 mg/L; and about 95 percent under 400 mg/L.

5.6.a Dissolved Solids Concentration in Stream Samples

Figure DS-1 presents all the data that passed the QA review for concentration of dissolved solids for all sites. The detection limit was 5 mg/L. A separate symbol represents each category of site to allow trends to be more easily observed.

Figure DS-1. Total Dissolved Solids Concentration for All Sites vs. Date - Lab 2 Only

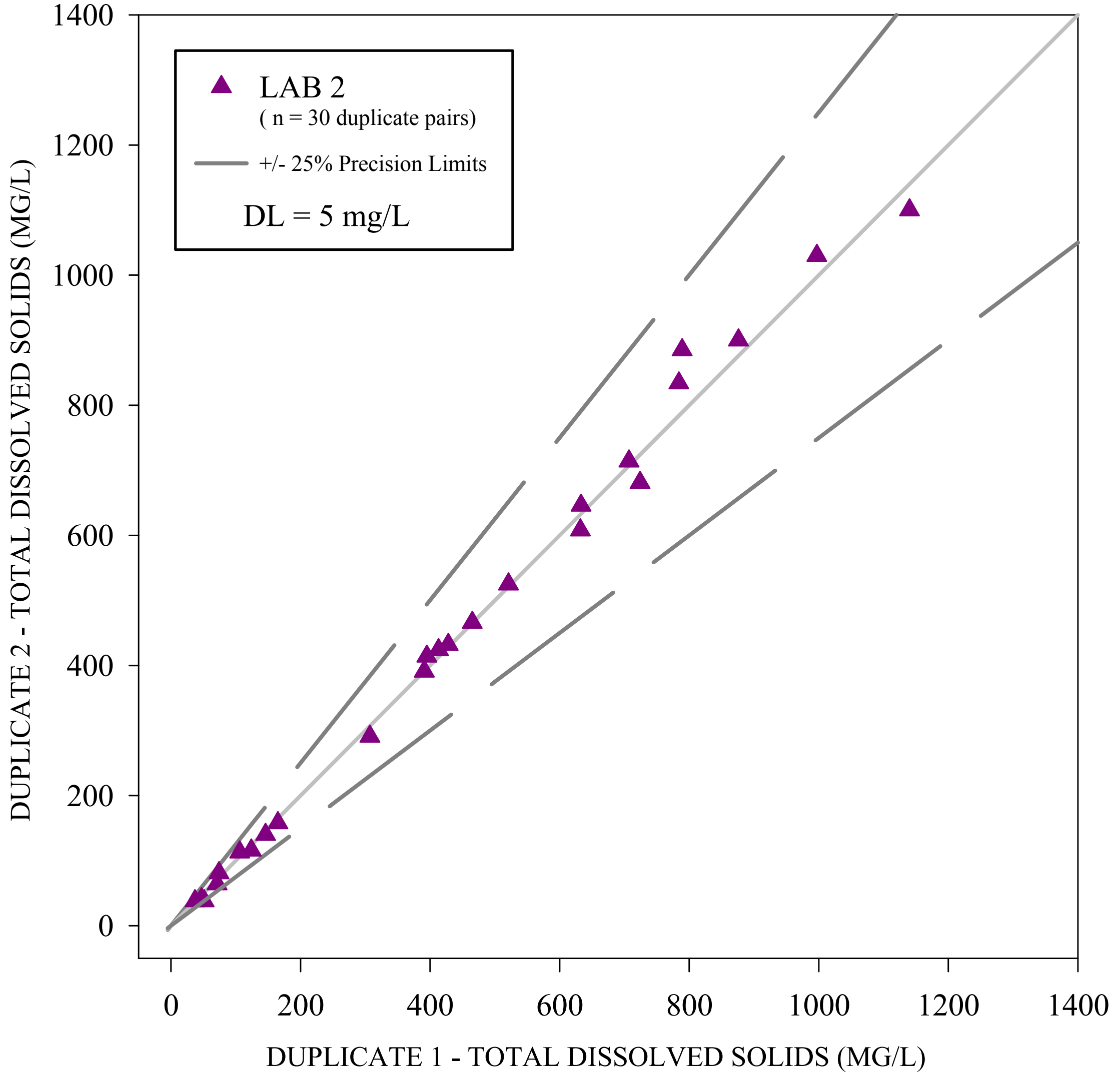


The QA review of data rejected 57 % of the values for dissolved solids at the first laboratory while 100 % of the values at the second laboratory passed the review. The values for all dissolved solids samples from the first laboratory were near zero while the values at the second laboratory range up to over 3,700 mg/L. There should have been high concentrations of dissolved solids during the first half of the study since sulfate and hardness were high. The data from the first lab was therefore not used in this evaluation.

5.6.b QA Samples for Dissolved Solids

A major reason for rejection of data at the first laboratory was excessive holding time before analysis. As for the blank samples, 27 of the 30 blanks at the first laboratory had detectable levels of dissolved solids. Only one of the 50 blanks tested at the second laboratory had measurable levels of dissolved solids. All 30 duplicate samples run at the second laboratory passed the QA/QC review. The results of duplicate samples are shown in Figure DS-2.

Figure DS-2. Comparison of Duplicate Samples-Total Dissolved Solids-Lab 2 Only



The duplicate samples results at the second laboratory are quite precise over a broad range of concentrations. The detection limit for dissolved solids was 5 mg/L which means the median value of 46 mg/L at Unmined sites is well above the limits of measurability. The dissolved solids values from the second laboratory have acceptable precision and can be used to evaluate the impacts of MTM/VF on stream water quality.

5.6.c Dissolved Solids Yield

Figure DS-3. Total Dissolved Solids Yield for All Sites vs. Date - Lab 2 Only

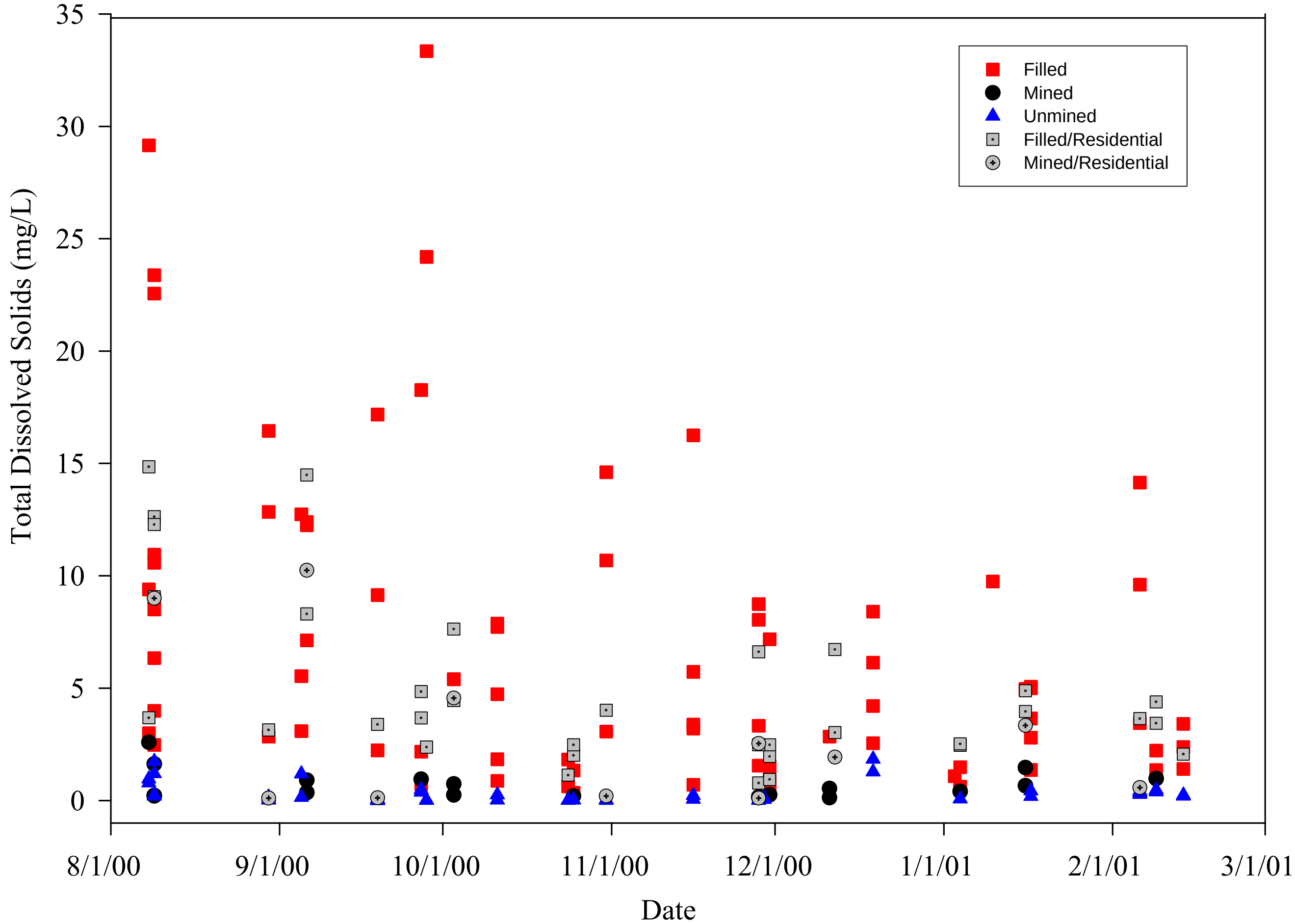


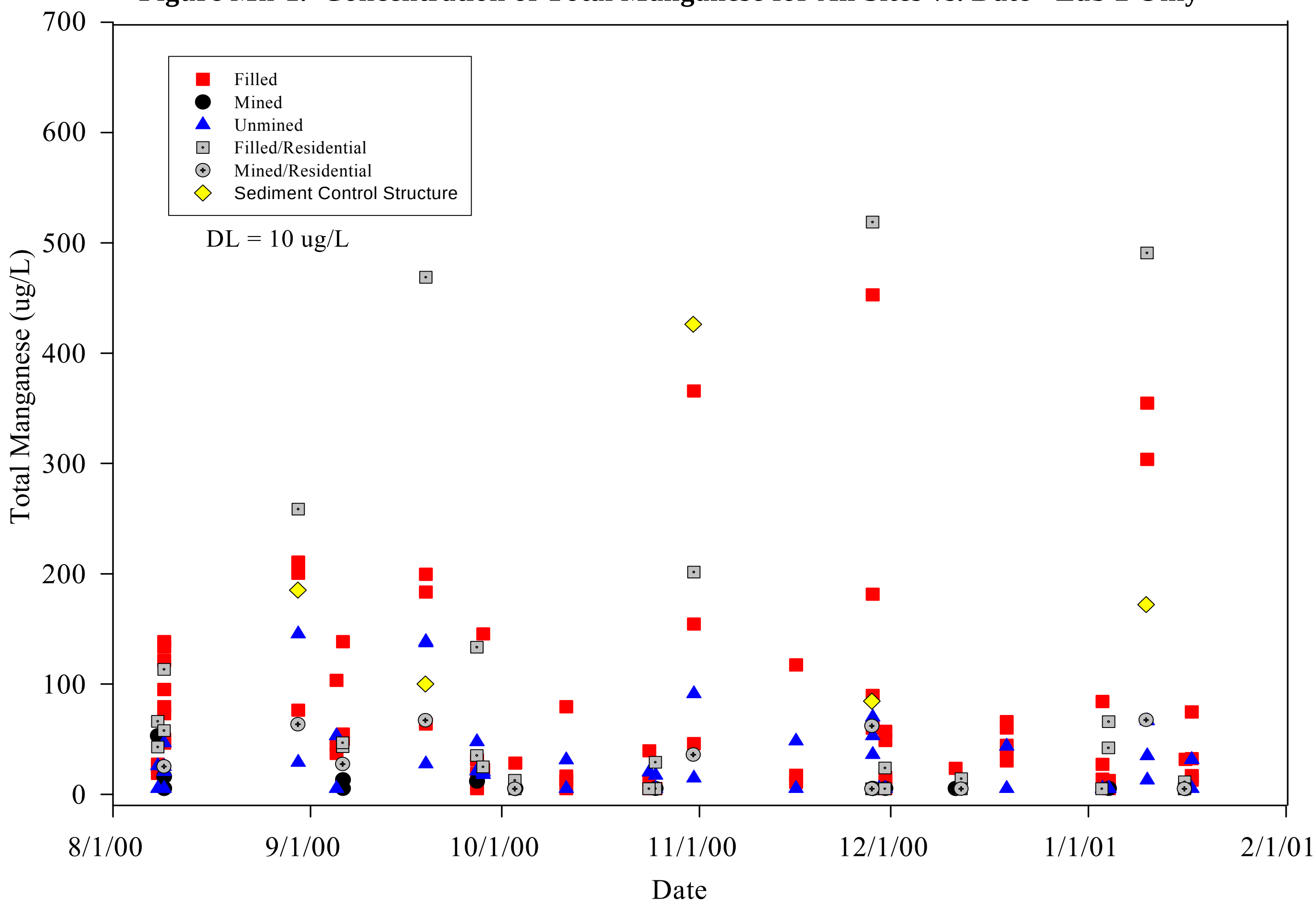
Figure DS-3 plots the Yield of dissolved solids for all sites. Yield rates for the second half of the study indicate Filled sites have elevated values of dissolved solids, up to 30 pounds per day per acre. Yield rates at Unmined sites are less than 2 pounds per day per acre.

5.7 Manganese, Total and Dissolved Data

There are discharge limits on total manganese for active mines set forth in the Code of Federal Regulations, Title 40, Part 434. The limits are 4.0 mg/L (4000 ug/L) maximum for any one day and 2.0 mg/L (2000 ug/L) maximum for thirty consecutive days. Although none of the monitoring points in this study is a discharge monitoring point for a permit, the limits serve as a reference when evaluating the concentrations in the streams. Manganese laden overburden is a concern for MTM/VF operations requiring special handling during the mining. The goal is to minimize leaching of manganese from the site in quantities that exceed the permit limit. There are reclaimed MTM/VF mines that continue to require chemical treatment of the discharges in order to comply with permit effluent limits (WVDEP CHIA for Twentymile Creek).

Data from the first lab lacked precision and was not included in this evaluation. Total manganese was detected in 70 % of the 210 samples analyzed at the second laboratory. The detection limit was 10 ug/L. It was found in all categories of sites and in all five watersheds studied. The maximum concentration of total manganese identified was 518 ug/L (site MT-23, category Filled/Residences, date - 11/28/00). This is about 12 % of the daily maximum effluent limit for coal mines. The maximum value detected at any Unmined site was 145 ug/L (MT-13, date - 08/30/00). Manganese concentration data is presented in Figure Mn-1. The higher values are generally at sites in the category "Filled", but the values are not consistent for specific sites.

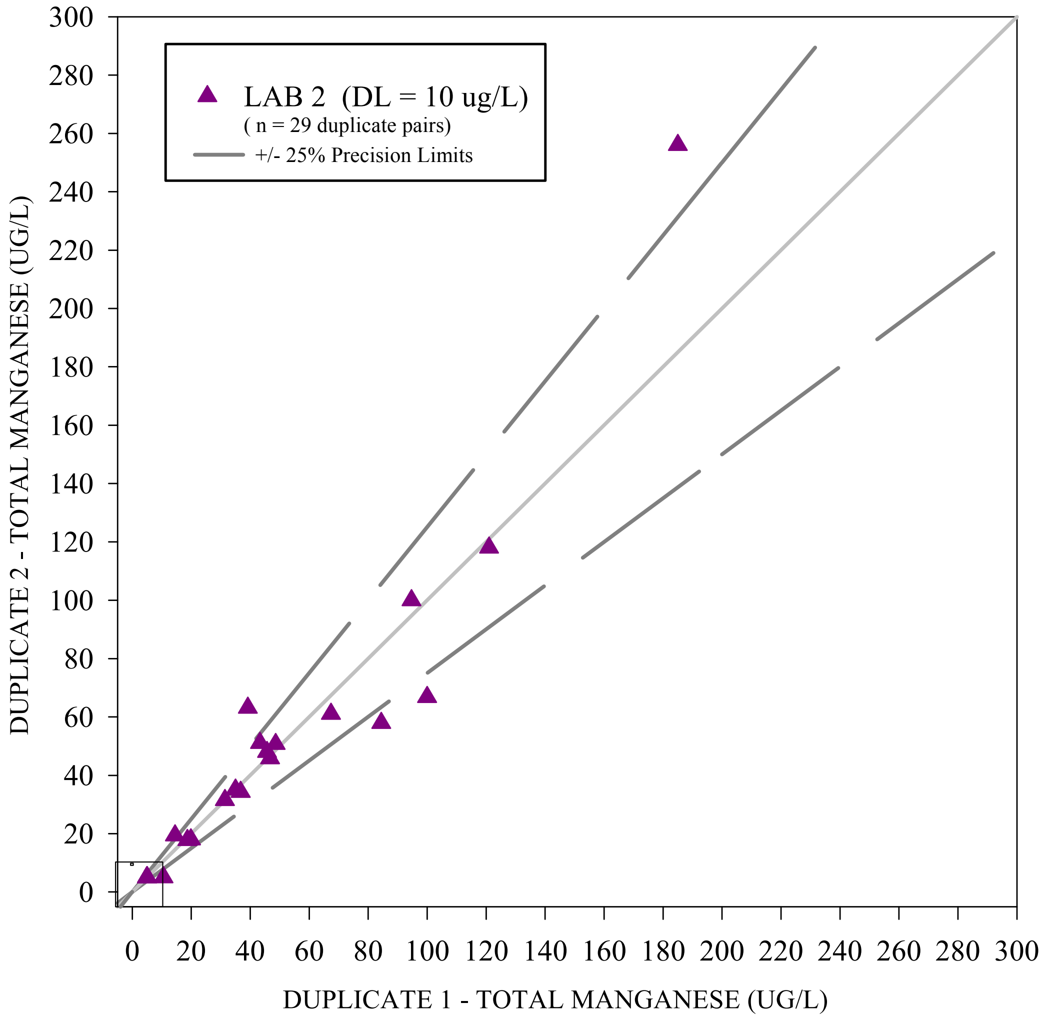
Figure Mn-1. Concentration of Total Manganese for All Sites vs. Date - Lab 2 Only



An example is range of concentrations for the Sediment Control Structure (MT-24) which go from less than 100 ug/L to more than 400 ug/L. The highest values were at site MT-23, which is the Mud River near the town of Mud. The manganese values at sites throughout the Mud River watershed are the higher values in this figure. Site MT-13, the mouth of Spring Branch in the Mud River watershed, is an Unmined site which had manganese values of 145 ug/L on 8/30/00 and 137 ug/L on 9/19/00. These higher values were associated with low flows (13 gpm and 0.5 gpm respectively) as the concentration at this site dropped below the detection limit when the flow rose to 150 gpm in February.

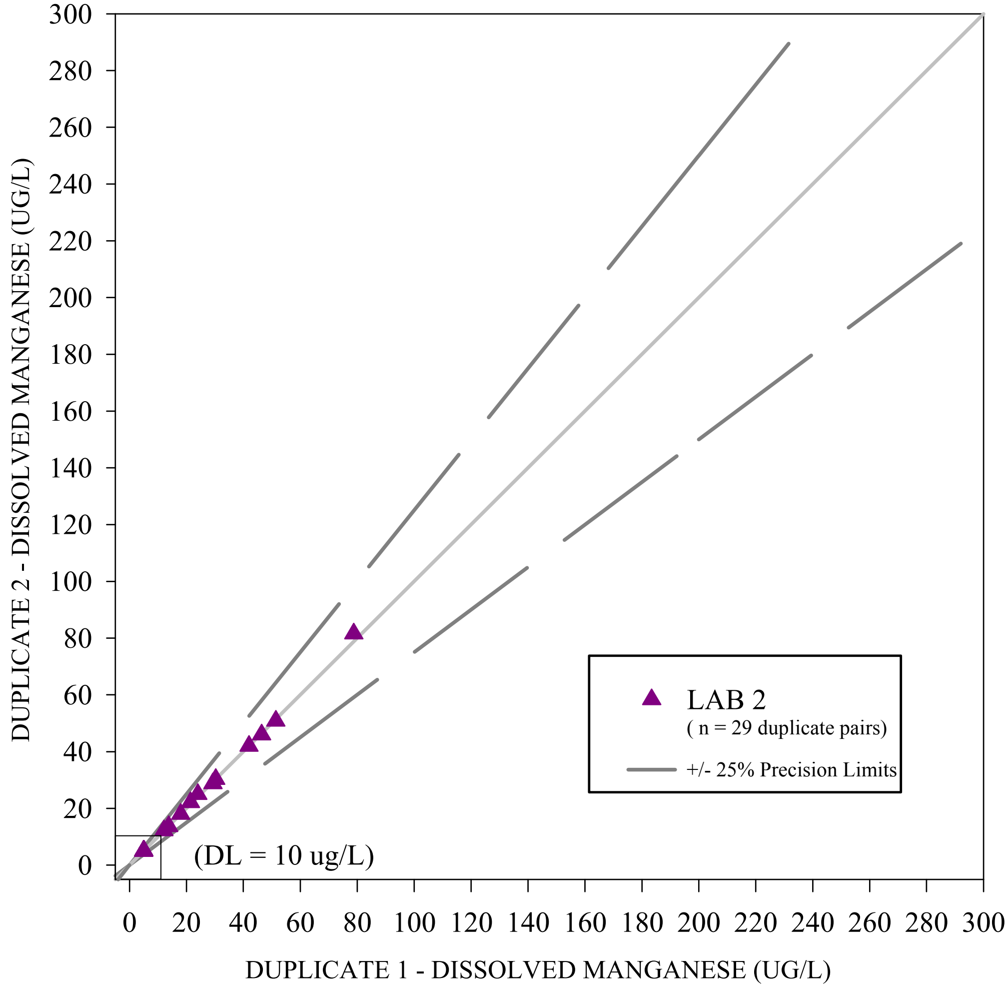
Figure Mn-2 plots the concentration of duplicate samples. The precision is only fair at the second lab. The values range up to about 25 times the detection limit.

Figure Mn-2. Comparison of Duplicates - Total Manganese - Lab 2 Only



Dissolved manganese was also measured in this study. Results of duplicate samples for dissolved manganese are plotted in Figure Mn-3. Precision is better than that for total manganese, but the range of concentration is smaller, being only about 8 times the detection limit.

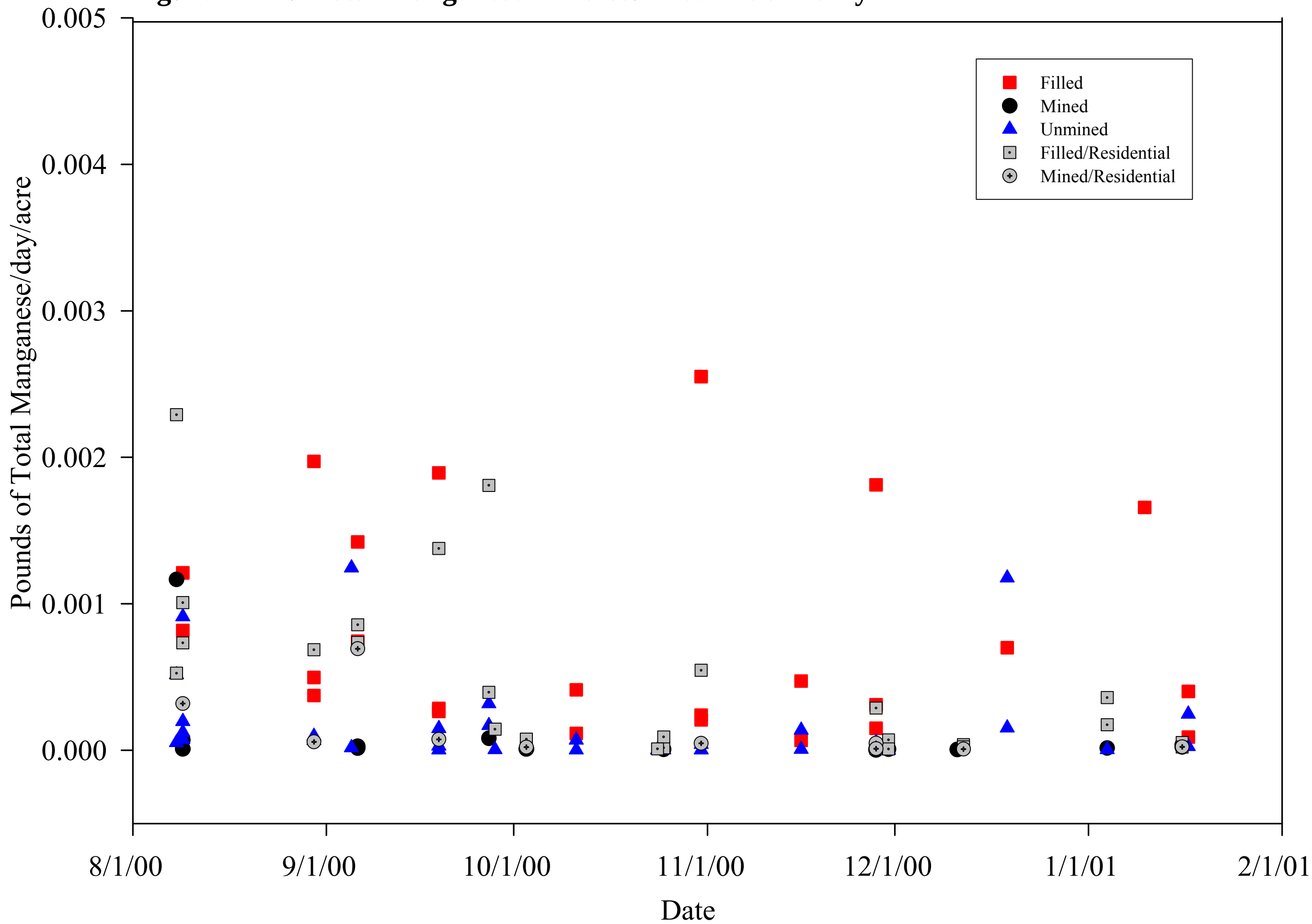
Figure Mn-3. Comparison of Duplicates - Dissolved Manganese - Lab 2 Only



The data for manganese indicate it occurs across the study area. MTM/VF mining can increase the concentration of manganese in streams and require long term chemical treatment of discharges. Careful analysis and special handling of mine overburden is required to minimize the concentration of manganese in permitted wastewater discharges from MTM/VF mines.

Yield rates for manganese are presented in Figure Mn-4 for the second laboratory only. Yield rates are all less than 0.003 pounds per acre per day and the higher values are from most categories of sites. This indicates that higher manganese values in streams are not closely related to mining activities and that mines are complying with permit limits on manganese.

Figure Mn-4. Total Manganese Yield vs. Date - Lab 2 Only



5.8 Specific Conductance Data

Specific conductance or conductivity is a quick method of measuring the ion concentration of water. The 18th Edition of *Standard Methods for the Examination of Water and Wastewater* states:

> Conductivity is the measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions: on their total concentration, mobility, and valence: and on the temperature of measurement. Solutions of most inorganic compounds are relatively good conductors. Conversely, molecules of organic compounds that do not dissociate in aqueous solution conduct a current very poorly, if at all.

The unit of measure is micromhos per centimeter or in the International System of Units, millisiemens per meter. Specific conductance is measured in the field using a calibrated meter. The median conductance value of samples from site MT-24 was 2,856 while the median conductance of all samples at Unmined sites was 62.6 micromho/cm, indicating higher concentrations of ions came from the area upstream of MT-24 site.

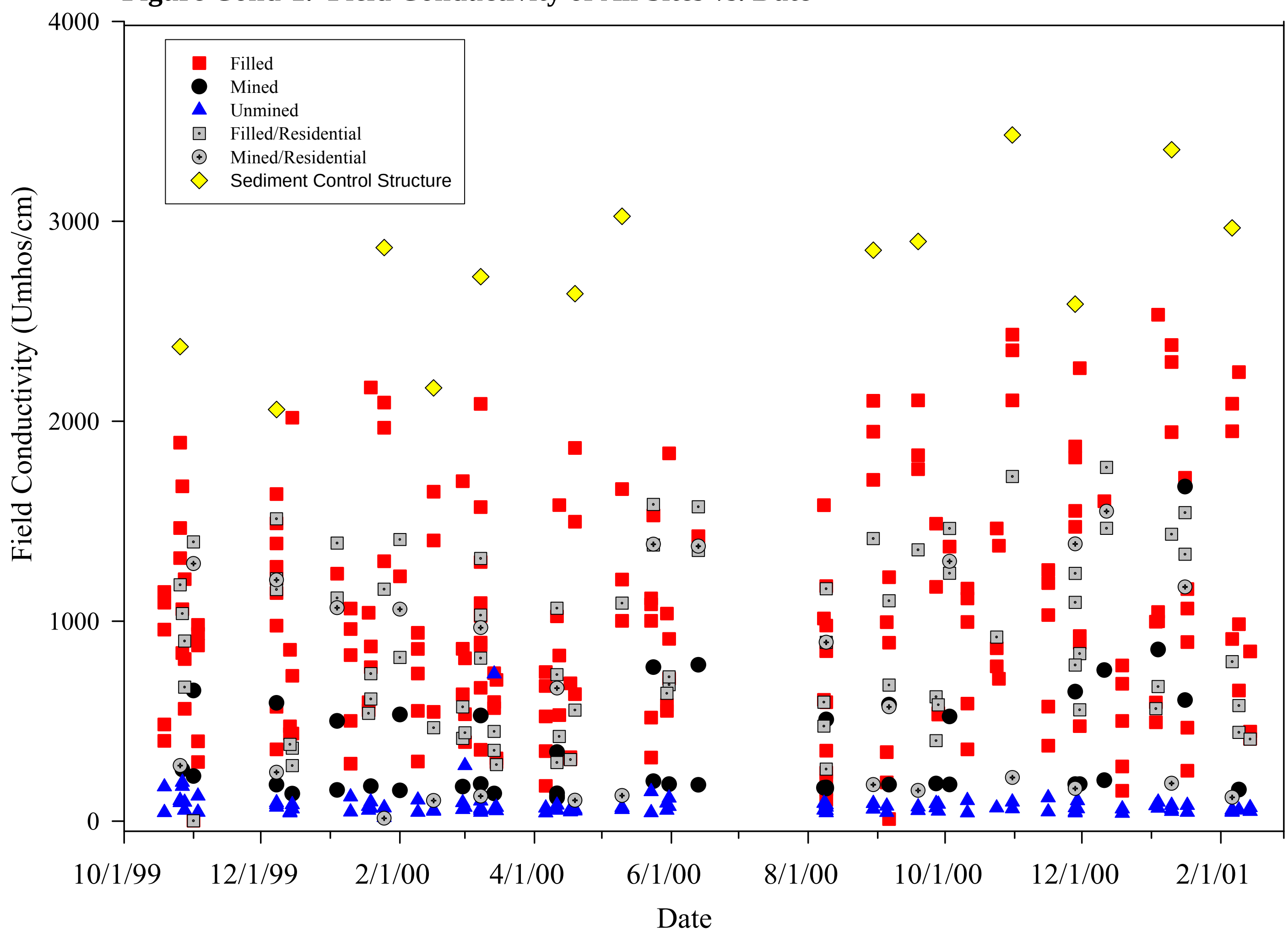
Although there is no stream criterion for conductivity in West Virginia, it is commonly measured as part of streams surveys. Regarding the impact of conductivity on fish and aquatic life, the California State Water Resources Control Board's *Water Quality Criteria* states:

> .... Hart et al. have reported that among United States waters supporting a good fish fauna about 5 % have a specific conductivity under $50x10^{-6}$ mhos [50 micromhos/cm] *at 25°C; about 50 percent under 270x* 10^{-6} *mhos* [270 micromhos/cm]*; and about 95 percent under* $1100x10^{-6}$ *mhos* [1100 micromhos/cm].

The conductivity of the streams during the sampling event has been included in Figure Cond-1. A different symbol has been used for each category of site so evaluation of trends is more evident. Conductivity at Filled sites can be 100 times greater than that at Unmined sites. The highest values are consistently at the Sediment Control Structure (MT-24) which is on a reclaimed MTM/VF mine.

It is no surprise that MTM/VF operations increase the conductance of streams draining the disturbed areas. Figure Cond-2 plots the conductivity vs the normalized flow rate (the flow rate measured at the time of sampling divided by the drainage area for that site)for two categories of sites - Filled and Unmined. Unmined sites have a consistently low conductivity no matter what the flow. Filled sites have a broad range of conductivity much higher than Unmined sites indicating that MTM/VF mining increases specific conductance in streams. In larger drainage area sites it is common to have lower flows associated with higher conductivity. This is discussed at the end of this report under the topic Flow Rate Data.

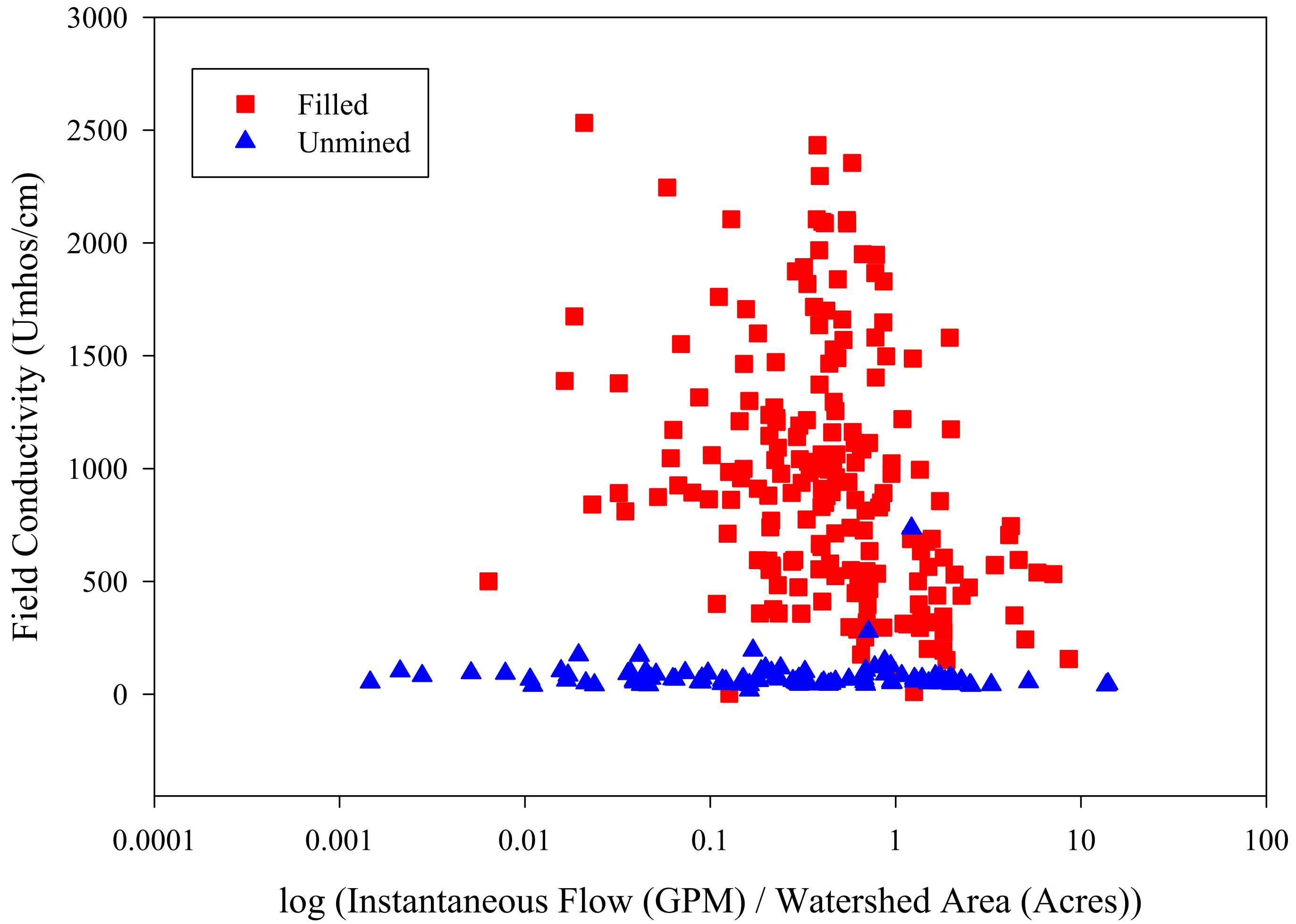
Figure Cond-1. Field Conductivity of All Sites vs. Date



5.9 Selenium Data

The selenium data indicate numerous violations of the West Virginia stream water quality criterion related to MTM/VF mining. Further discussion of selenium results is located in the

Figure Cond-2. Field Conductivity vs. Instantaneous Flow / Watershed Area



section of this report describing compliance with stream water quality criteria.

5.10 Alkalinity Data

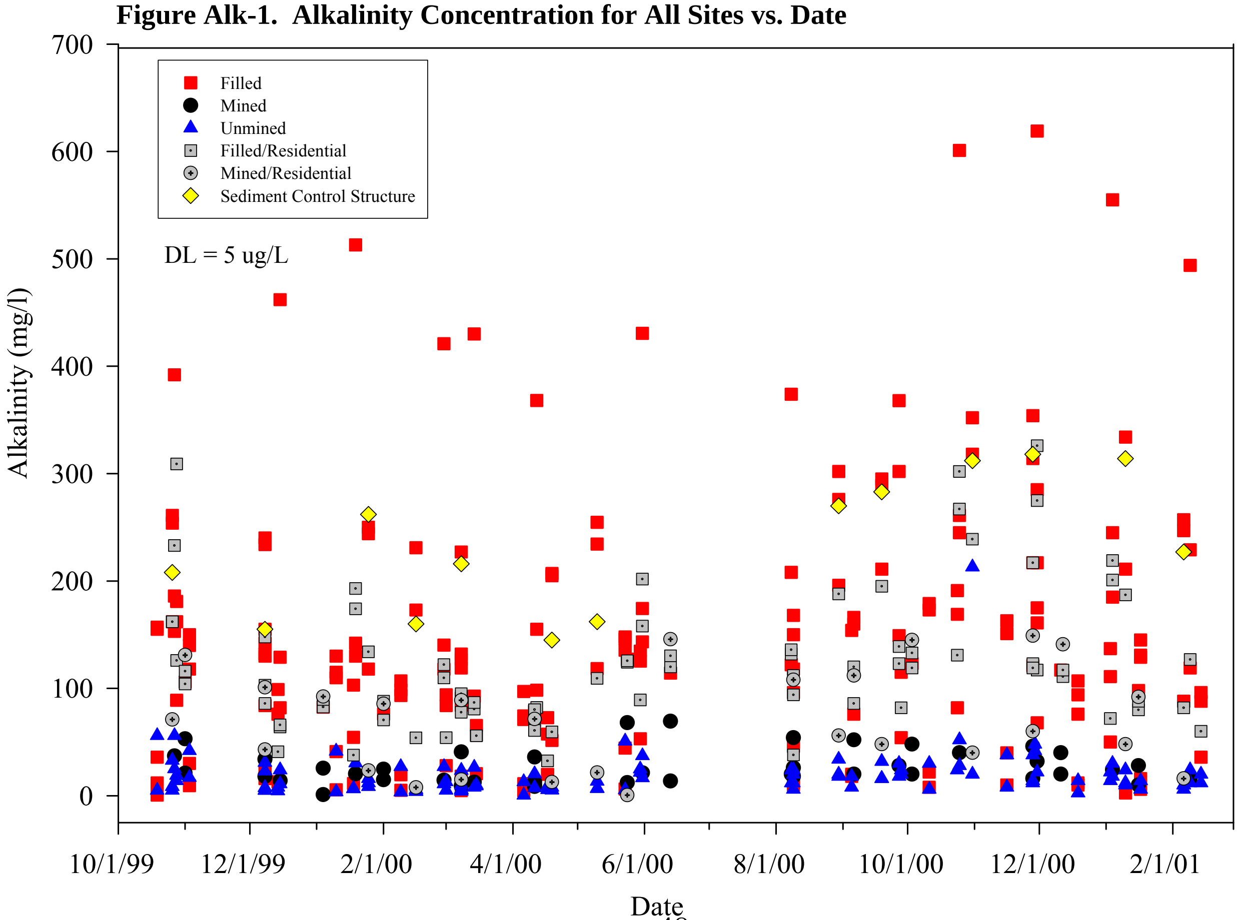
According to the 18th Edition of Standard Methods, alkalinity of a water is its acid-neutralizing capacity and is primarily a function of carbonate, bicarbonate, and hydroxide content. Alkalinity is not a specific substance but rather combination of substances. Regarding the impact of alkalinity on aquatic life, the California State Water Resources Control Board's *Water Quality Criteria* states:

> It is generally recognized that the best waters for support of diversified aquatic life are those with pH values between 7 and 8, having a total alkalinity of 100 to 120 mg/L or more. This alkalinity serves as a buffer to help prevent any sudden change in pH value, which might cause death to fish or other aquatic life.

5.10.a Alkalinity Concentration in Stream Samples

The concentration of alkalinity in samples from all sites vs date are plotted in Figure Alk-1. The detection limit was 4 mg/L. Values for many Filled sites are several times higher than the Unmined sites. Twelve of the thirteen highest values are from site MT-34B and those concentrations are even higher than the values at the Sediment Control Structure which is on a reclaimed MTM/VF mine. The increase in alkalinity at a MTM/VF mine site is sometimes augmented by liming of areas being reclaimed to improve vegetation growth or by addition of alkaline materials during the mining process to line ditches to neutralize acidic materials. There are also some chemical treatment facilities upstream of some sites. These facilities usually add excess alkalinity as they neutralize acid mine drainage or remove manganese to comply with

Figure Alk-1. Alkalinity Concentration for All Sites vs. Date

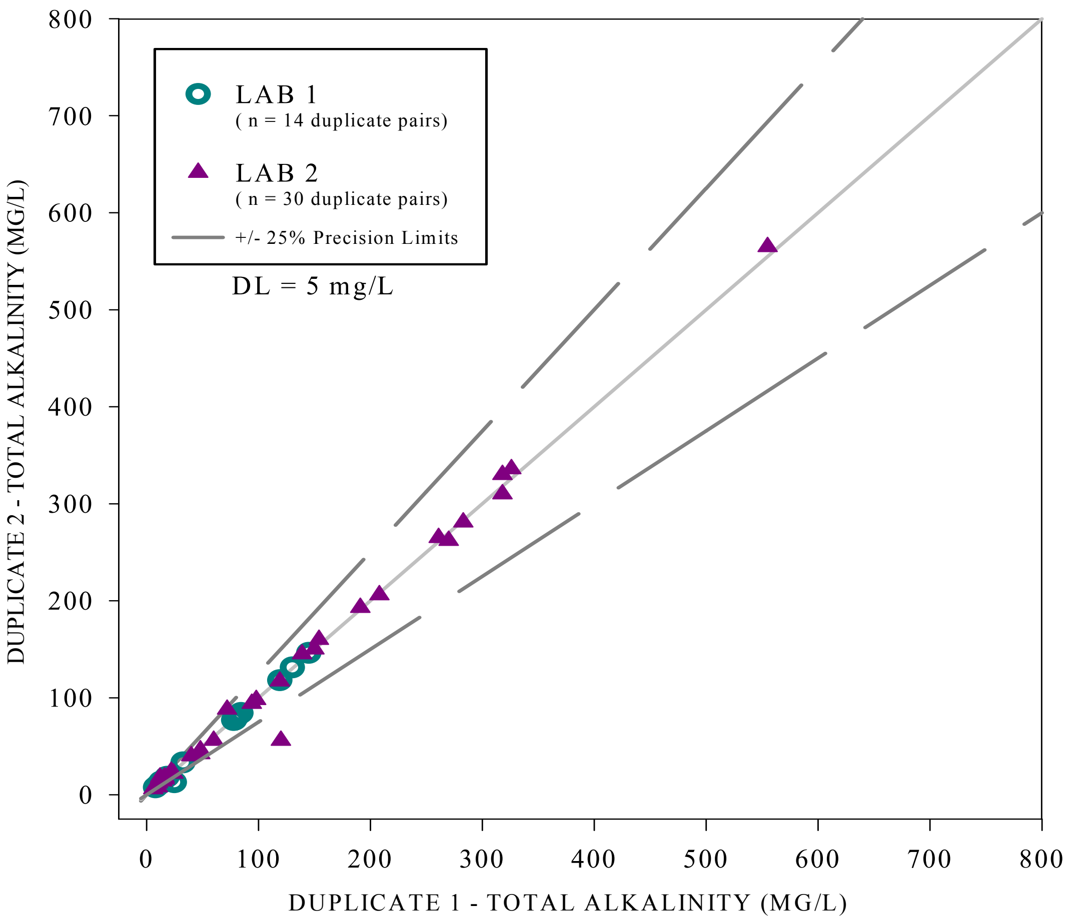


permit limits on discharges. These factors also influence other parameters like specific conductance, dissolved solids, and hardness.

5.10.b QA Samples for Alkalinity

Figure Alk-2 presents a plot of the concentration of duplicate samples. Data from both laboratories is precise over a range from the detection limit of 5 ug/L to a maximum of 600 mg/L

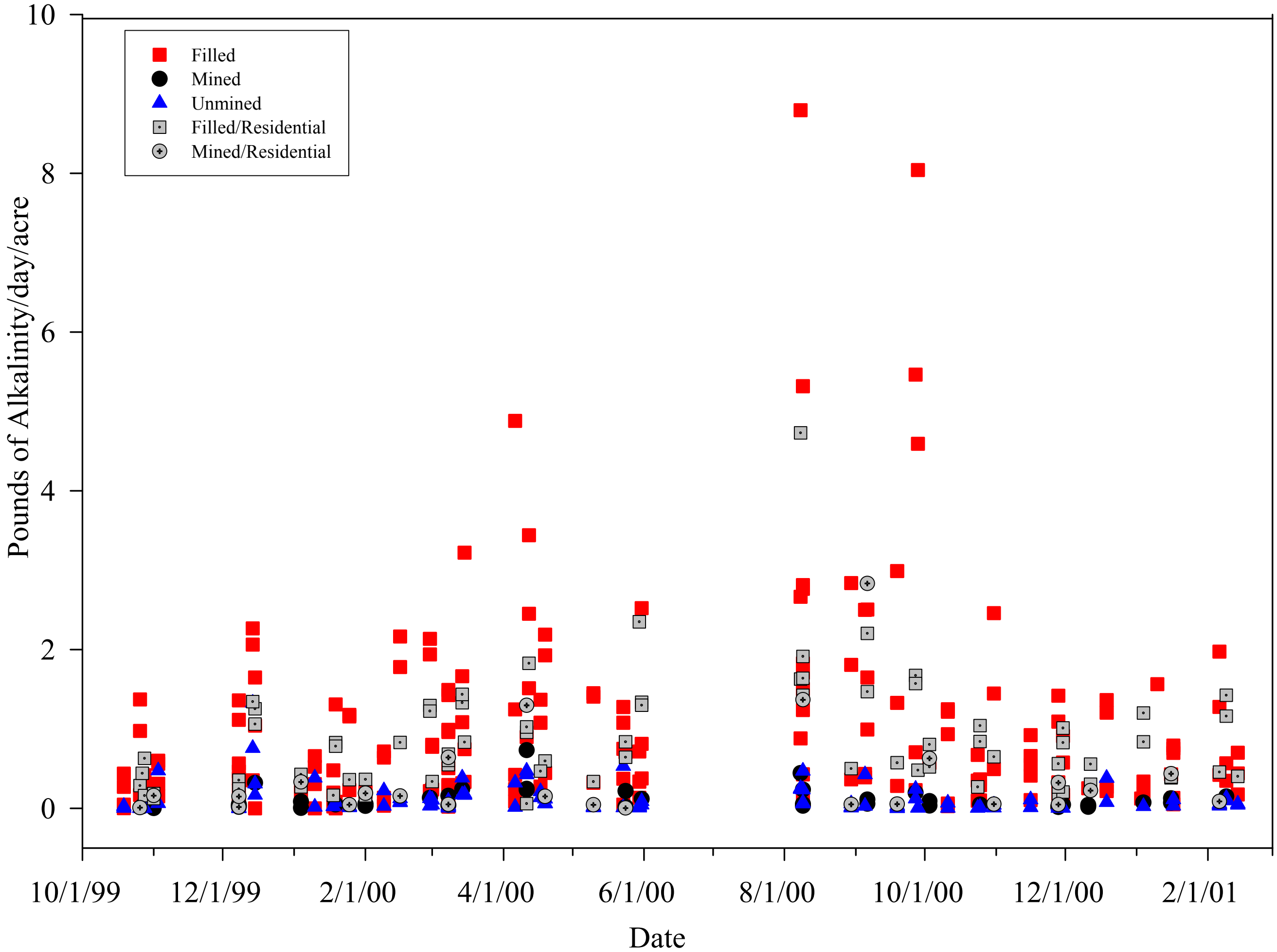
Figure Alk-2. Concentration of Duplicate Samples for Alkalinity



5.10.c Alkalinity Yield

Figure Alk-3 plots the Yield of alkalinity

Figure Alk-3. Alkalinity Yield for All Sites vs. Date



for all samples. Yield rates for Unmined sites are less than 1 pound per day per acre while Yield rates at Filled sites range to 5 pounds per day per acre. There appears to be a slight decrease in alkalinity yield during fall and winter months. The highest yield was at MT-34B in August 2000. Other high yield values are from various sites scattered across the study area.

5.11 Potassium Data

The California State Water Resources Control Board's *Water Quality Criteria* reports that potassium is a common element constituting 2.4 percent of the earth's crust. Potassium salts are extremely soluble and can usually only be removed from water through evaporation. Potassium is an essential nutritional element for humans but acts as a cathartic in concentrations greater than 2000 mg/L. Regarding impacts to fish and other aquatic life, the report states:

> The toxicity of potassium to fish is reduced by calcium, and, to a lesser degree, by sodium. Potassium is more toxic to fish and shellfish than calcium, magnesium, or sodium. ... Several investigators found, independently, that potassium could be toxic to fish in soft or distilled waters at concentrations of 50-200 mg/L .....

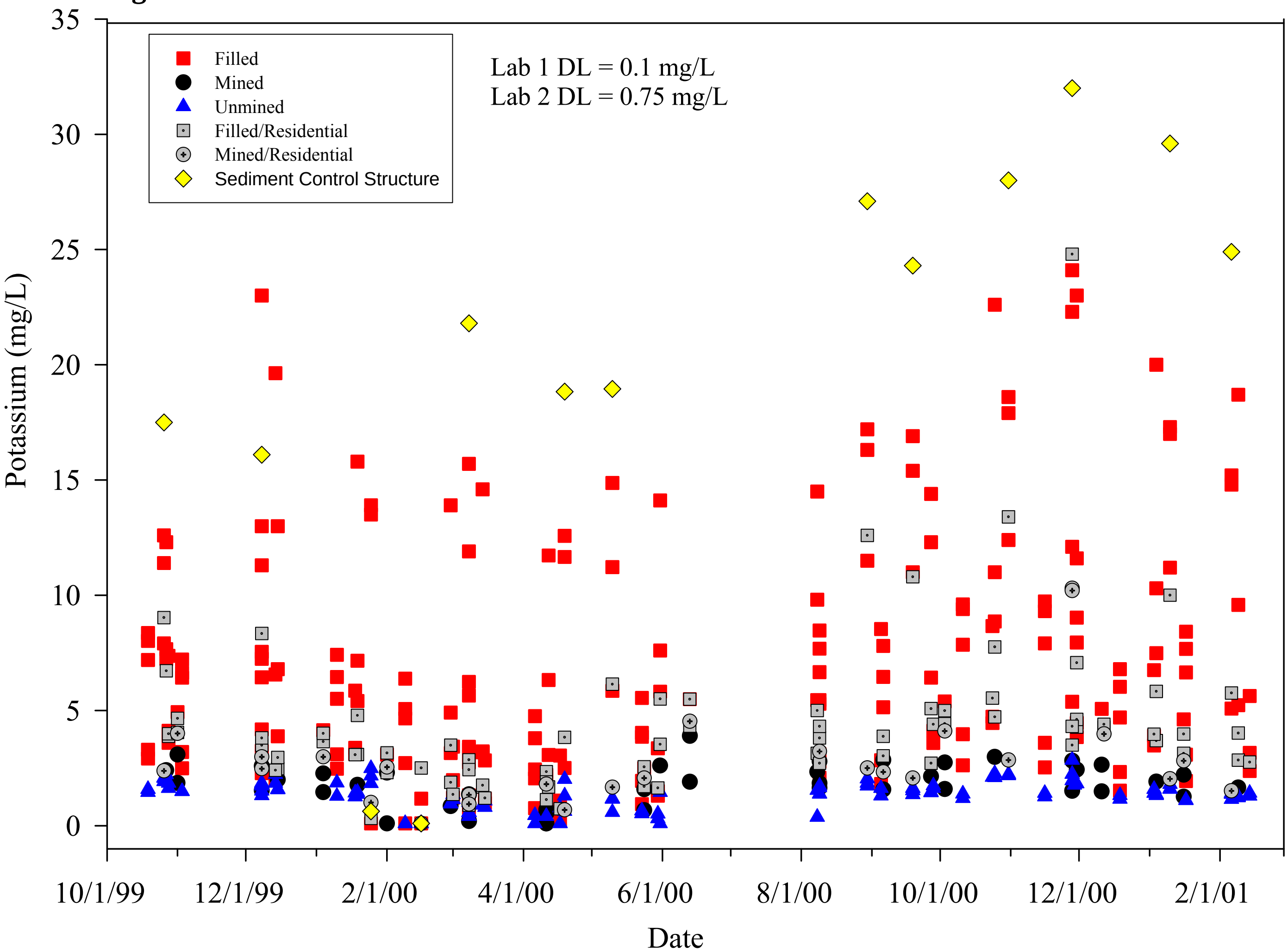
Potassium is a component of many fertilizers which are sometimes applied to mined areas to stimulate vegetation growth. This practice could be augmenting the increase of potassium in streams below mine sites being reclaimed.

5.11.a Potassium Concentration in Stream Samples

Figure K-1 shows the concentration of potassium in samples from all sites vs date. The detection limit was 0.1 mg/L for Laboratory 1 and 0.75 mg/L for Laboratory 2. The potassium data from both laboratories passed the QA review with only two samples being rejected and those were at Laboratory 1.

The higher concentrations are consistently at sites in the Filled category indicating that MTM/VF

Figure K-1. Concentration of Potassium for All Sites vs. Date

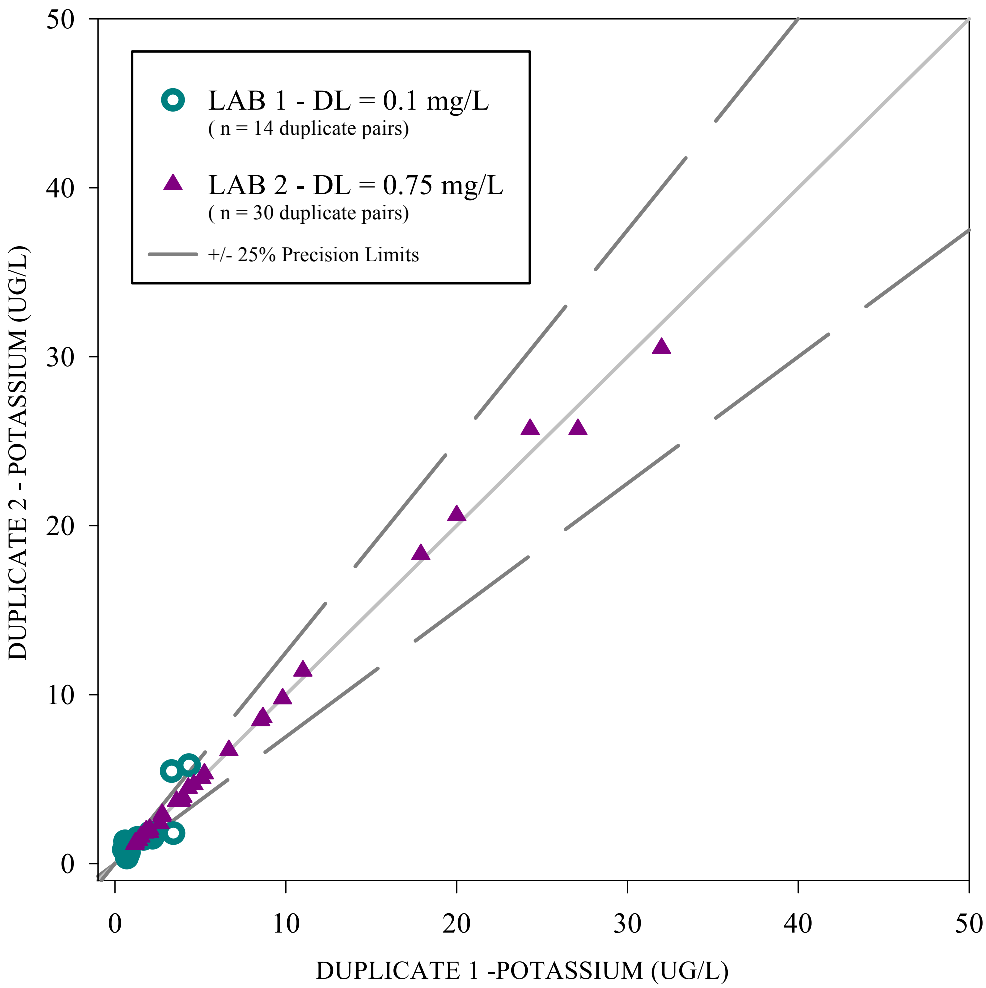


mining operations increase the concentration of potassium in streams. There are 40 values above 10 mg/L and 29 of those are in the Mud River, 10 in the Spruce Fork, and one in the Clear Fork watersheds. All sites in the Unmined category have low concentrations of potassium.

5.11.b QA Samples for Potassium

Figure K-2 plots the concentration of potassium in all duplicate samples collected during this study. The plot indicates the data are more precise at the second laboratory over the range of concentrations from the detection limit to about 30 mg/L.

Figure K-2. Comparison of Duplicate Samples - Potassium

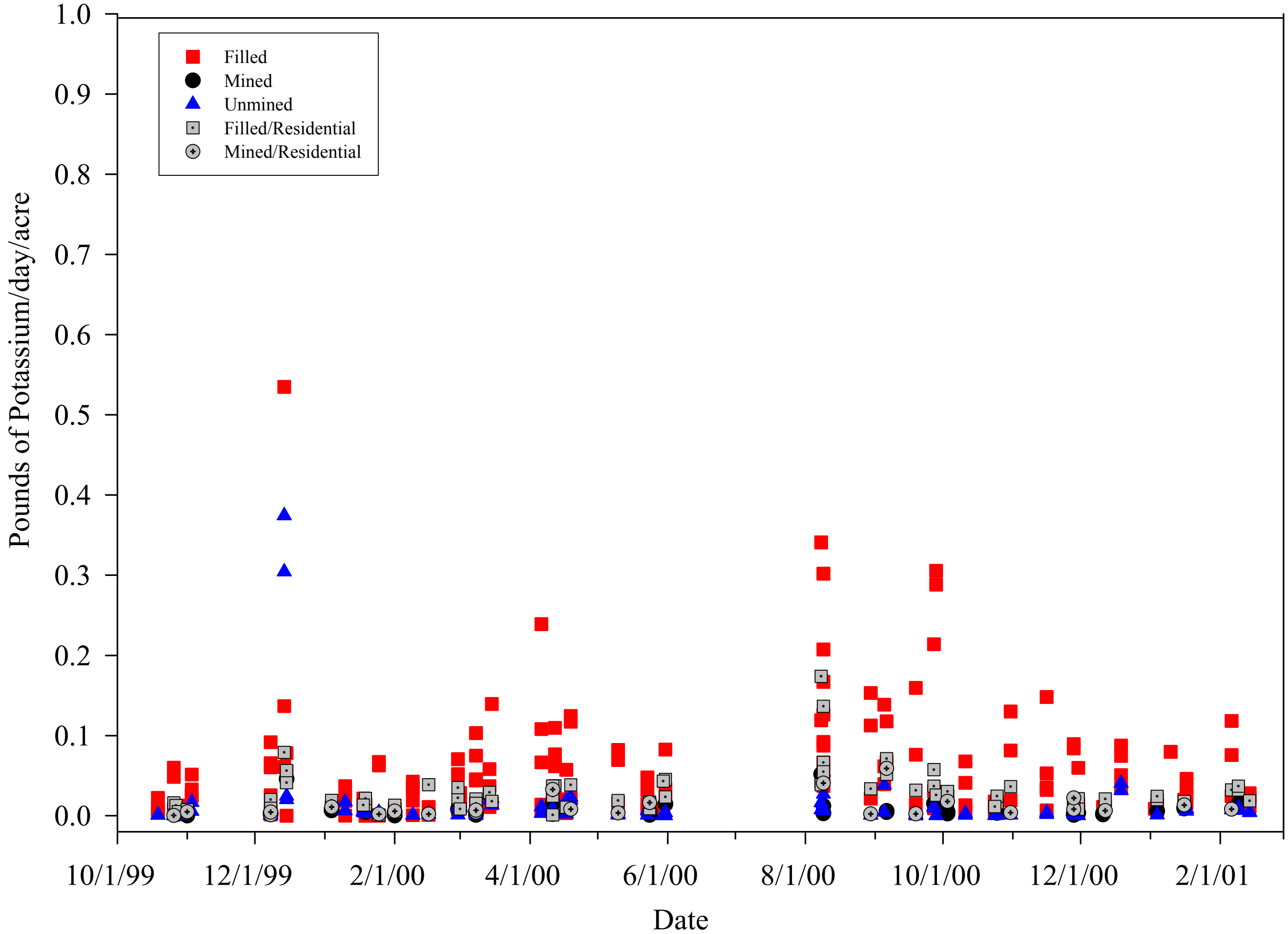


5.11.c Potassium Yield

Figure K-3 plots the Yield of potassium for samples from all sites vs date. The data would indicate that potassium Yield rates are generally below 1 pound per day per acre, but the higher values are usually from sites in the Filled category. The three higher yield values for samples collected in December 1999 are all in the same watershed. They are sites MT-50, 51, and 52. The yield rates are believed to elevated on this occasion due to recent rains. The note on the field sheet states "Heavy precipitation in the last 24 hours." None of the higher concentrations for the December 1999 samples were from these three sites so the increase in flow rates resulted in higher yield rates.

5.12 Sodium Data

Figure K-3. Potassium Yield for All Sites vs. Date



The California State Water Resources Control Board's *Water Quality Criteria* states:

> This very active metal does not occur free in nature, but sodium compounds constitute 2.83 percent of the crust of the earth. Owing to the fact that most sodium salts are extremely soluble in water, any sodium that is leached from soil or discharged by industrial wastes will remain in solution.

Regarding the impact on fish and aquatic life, the report states:

> Of the United States waters supporting good fish fauna, ordinarily the concentration of sodium plus potassium is less than 6 mg/L in about 5 percent; less than 10 mg/L in about 50 percent; and less than 85 mg/L in about 95 percent.

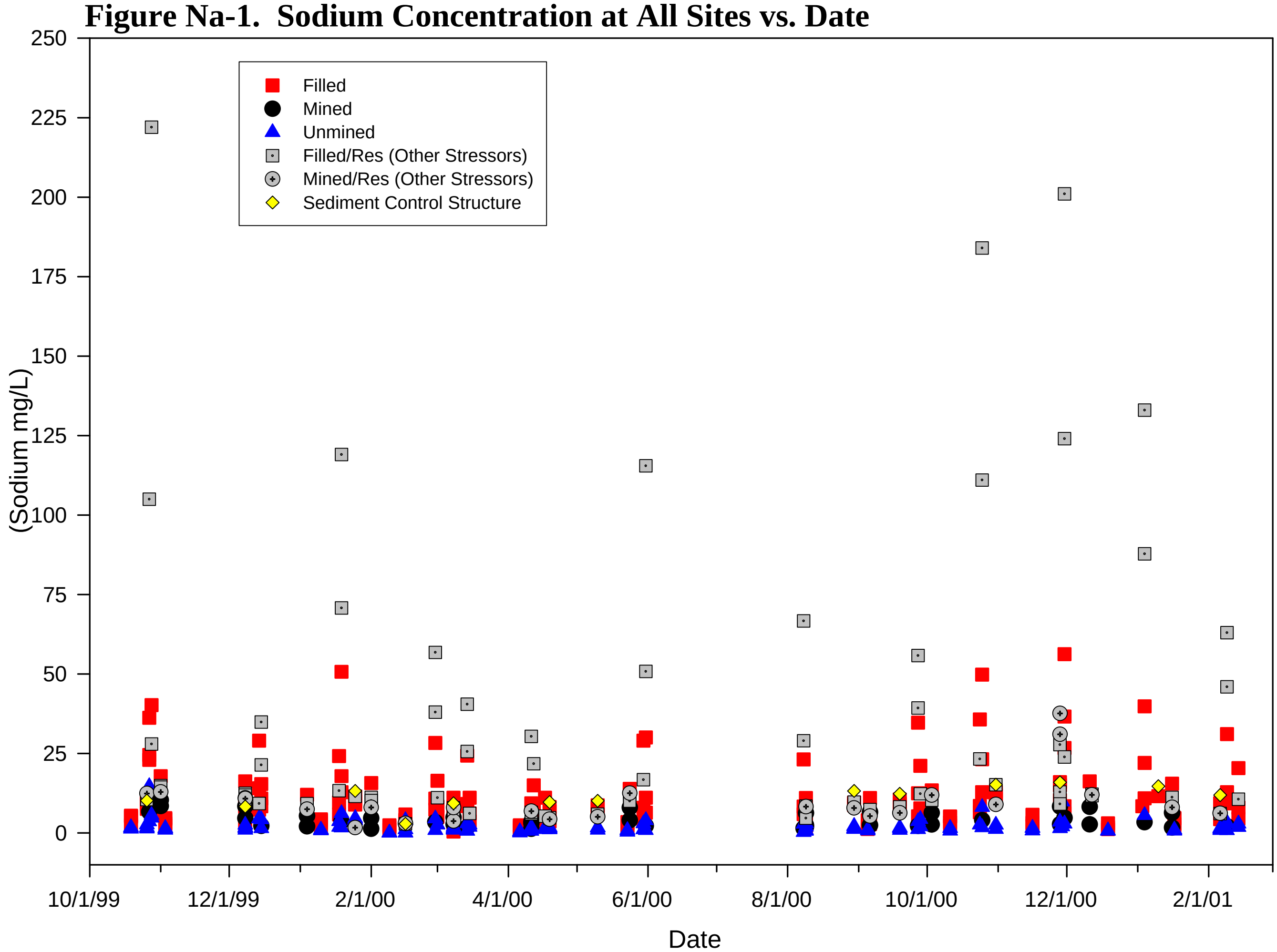
5.12.a Sodium Concentration in Stream Samples

Sodium concentrations for all sites are plotted in Figure Na-1. The detection limit was 1 mg/L The highest values are for sites in the category Filled/Residences and occurred in the Spruce Fork watershed at sites MT-40 and MT-48. MT-40 is downstream of 7 MTM/VF mine permits and 3 refuse piles while MT-48 is below four communities. Possible sources of sodium would be mine drainage treatment facilities using sodium hydroxide and winter time salting of highways.

5.12 c QA Samples for Sodium

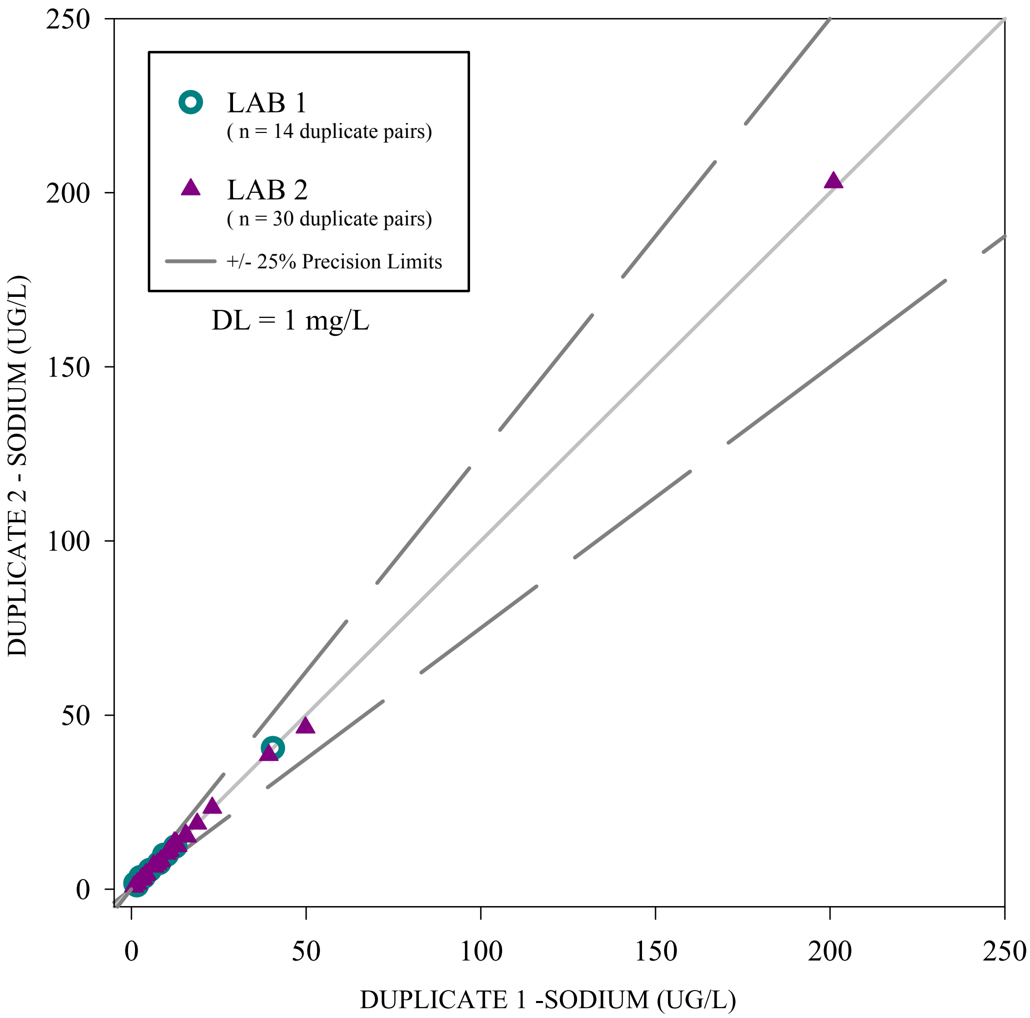
The results of duplicate samples are plotted in Figure Na-2. The detection limit was 1 mg/L. The

Figure Na-1. Sodium Concentration at All Sites vs. Date



data are very precise with multiple values below about 60 mg/L. The one value at slightly over 200 mg/L also is very precise. Both laboratories have good precision for this parameter.

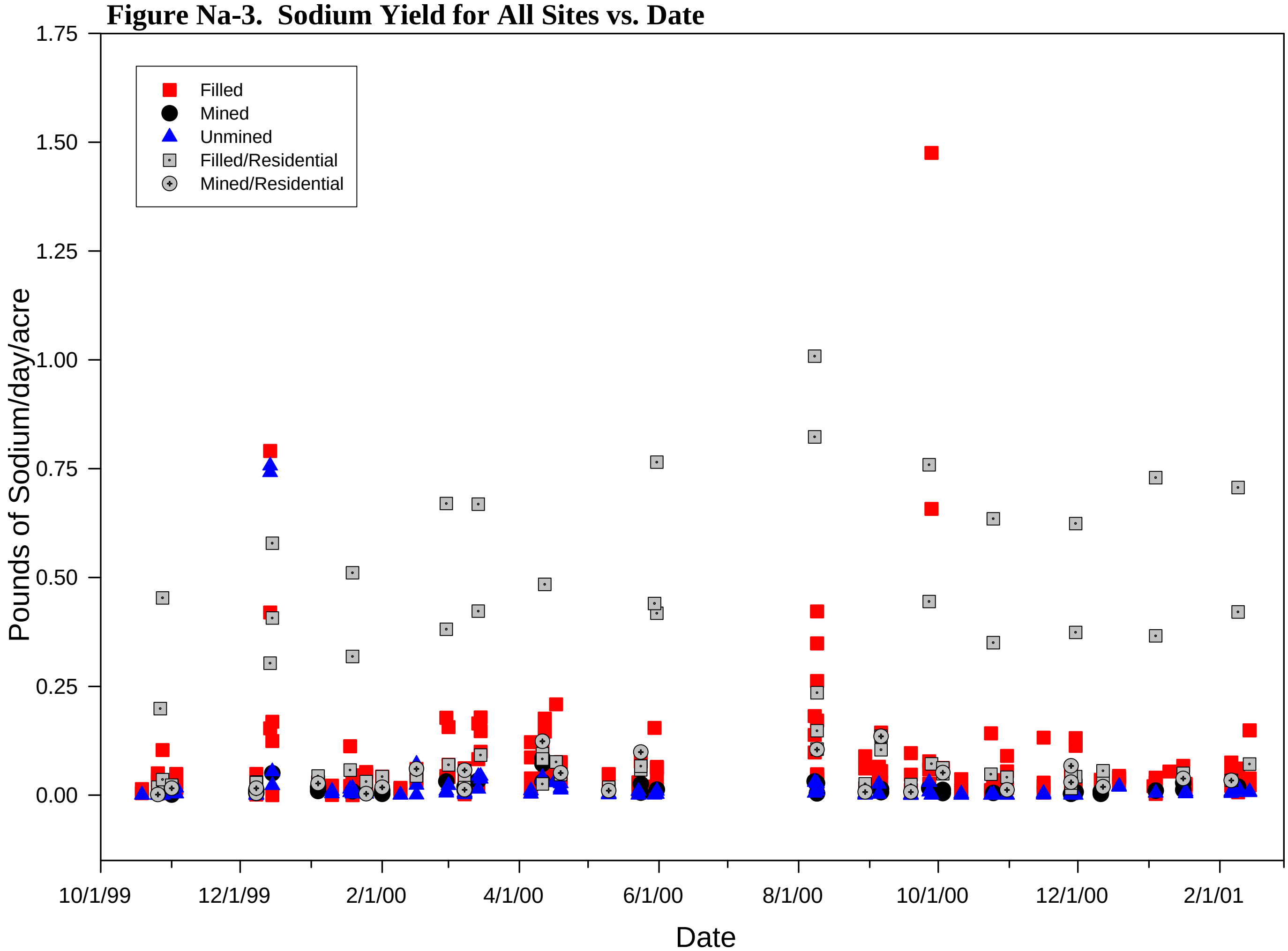
Figure Na-2. Sodium Concentration of Duplicate Samples



5.12.c Sodium Yield

Yield rates for sodium are plotted in Figure Na-3. Most values are less than 0.25 pounds per day per acre. The higher values at the Filled/Residence sties were noted in Figure Na-1 also and are possible related to use of road salt or the use of sodium hydroxide in chemical treatment facilities at mine discharges. There are higher values on two sample occasions - December 1999 and September 2000. The three values near 0.75 pounds per day per acre in December 1999 were at MT-50, 51, and 52. The field sheet not for those samples noted "Heavy precipitation in the last 24 hours." The higher yield rates for the Filled/ Residential sites is for MT-40 and MT-48, which correspond to the higher concentrations listed earlier in Figure Na-1 showing concentrations vs date. The highest yield of 1.5 pounds per day per acre is at site MT-60. The flow rate for that sample was the highest recorded for that site during this study while the

Figure Na-3. Sodium Yield for All Sites vs. Date



concentration was 21.1 mg/L, below the average for that site (30.5 mg/L). There were no comments on the field sheet indicating anything unusual.

5.13 Chloride Data

Chloride is one of the parameters limited by WVDEP water quality criteria and is discussed later in the report under that topic.

5.14 Acidity Data

Acidity, like alkalinity is not a specific chemical but instead is a measure of the effects of a combination of substances and conditions in the water. Waters can have both acidity and alkalinity values at the same time. Acidity may be present from natural causes and from human activity. Acid waters are sometimes formed as a result of mining activity, especially in sulfur bearing formations. Regulations have sought to address concerns with excess acidity resulting from mining activities through the permitting processes. There are elaborate regulations which focus on determining and minimizing the potential for forming acid waters. There are also effluent limits on the pH (discussed later in this report) of discharges.

Acidity was detected in 20 % of the 399 samples that passed the QA/QC review. The second laboratory found acidity in 31 samples above the detection limit of 2 mg/L. Twenty of these detected values came from sites in the Filled category. The site with the highest concentrations of acidity was MT-34B, a site in the Filled category with an active mine upstream. Five of the 31 values came from this site and they ranged from 29 mg/L to 40 mg/L. However, there were no violations of the stream limits on pH at this site. The only violations of the stream criteria for pH detected were at Unmined sites.

Acidity in streams can be increased by MTM/VF mining but mine permitting activities address this potential problem.

5.15 Nitrate and Nitrite Data

The *Water Quality Criteria, 1972* "Blue Book" discusses Nitrate-Nitrite in water supplies and notes that chlorination converts the nitrite to nitrate. They make the following recommendation concerning nitrate in water:

> On the basis of adverse physiological effects on infants and because the defined treatment process has no effect on the removal of nitrate, it is recommended that the nitrate-nitrogen concentration in public water supply sources not exceed 10 mg/L. On the basis of its high toxicity and more pronounced effect than nitrate, it is recommended that the nitrite-nitrogen concentration in public water supply sources not exceed 1 mg/L.

The California State Water Resources Control Board's *Water Quality Criteria* also discusses nitrate and nitrite and notes that nitrites are often formed in streams by the natural degradation of ammonia and organic nitrogen. Since they are usually quickly oxidized to nitrates, they are seldom present in surface waters in significant concentrations. The presence of nitrates and nitrites usually indicates an organic loading source such as sewage or fertilizer. Regarding the impact on fish and other aquatic life, the report states:

> High nitrate concentrations in effluents and water stimulate the growth of plankton and aquatic weeds. By increasing plankton growth and the development of fish food organisms, nitrates indirectly foster increased fish production. Hart et al. report references to the effect that United States waters supporting a good fish life ordinarily 5 percent have less than 0.2 mg/L of nitrates; 50 percent have less than 0.9 mg/L; and 95 percent have less than 4.2 mg/L.

5.15.a Nitrate-Nitrite Concentration in Stream Samples

The laboratory data for nitrate and nitrite is somewhat confusing and of mixed quality, partly due to changes in what parameters were being measured. The first laboratory began this survey analyzing for nitrates and nitrites separately but it was soon evident that the 48 hour holding time was difficult to meet. The parameter was switched to nitrate - nitrite (nitrogen) which has a 28 day holding time for the contract with the second laboratory. The data from the first laboratory was often rejected for holding time violations and only 54 % of the nitrate samples and 66% of the nitrite samples passed the QA review. The second laboratory began testing for nitrate and nitrite separately but soon switched to nitrate plus nitrite as nitrogen. The first samples at the second laboratory were manually converted to nitrate plus nitrite as nitrogen values and entered into the database. Overall 94 % of the data from the second laboratory for nitrate plus nitrite as nitrogen passed the QA/QC review. The detection limit was 0.1 mg/L. The highest value detected at the second laboratory was 23.4 mg/L at site MT-18, a site in the Filled category, on 01/10/00. Some high values might be caused by careless handling of the nitrogen compound explosives used at surface mines or when nitrogen containing fertilizers are spread on surface mines to encourage growth of vegetative cover during reclamation, but it is not known if this might be part of the cause for this elevated value. Many samples had no detectable concentrations and they were in all categories of sites. The Unmined site with the most detectable concentrations and the highest values (second lab data only) was MT-95 in the Twentymile Creek watershed. Nitrate plus nitrite as nitrogen values ranged from 0.73 mg/L to 1.1 mg/L in each of the six samples from the site.

MTM/VF mining operations can increase the concentration of nitrate plus nitrite as nitrogen in streams.

5.16 Parameters Present in Low Concentrations

5.16.a Total Phosphorous

Phosphorous was detected in only one of 213 samples at the second laboratory. The concentration was 0.12 mg/L. No samples were rejected in the QA/QC review. Since the detection limit was 0.10 mg/L, this would indicate that stream concentrations of phosphorous are not being measurably impacted by MTM/VF mining.

5.16.b Total Copper, Lead and Nickel

Copper, lead, and nickel were usually below the detection limit for all samples tested at the second laboratory but several samples had detectable concentrations as listed below. The only obvious pattern observed in the data is that many of the detections were in the Mud River watershed (MT-01 through MT-24). Site MT-24, a site on a reclaimed MTM/VF mine, had three measurable values of copper, all near the detection limit, no nickel values, and six of the eight detections for nickel. There is no clear indication that MTM/VF mining caused any changes in these metal concentrations in streams.

Site ID	Category	Date	Copper (DL = 5 ug/L)	Lead (DL = 2 ug/L)	Nickel (DL= 20 ug/L)
MT-01	Min/Res	01/10/01	10.3	ND	ND

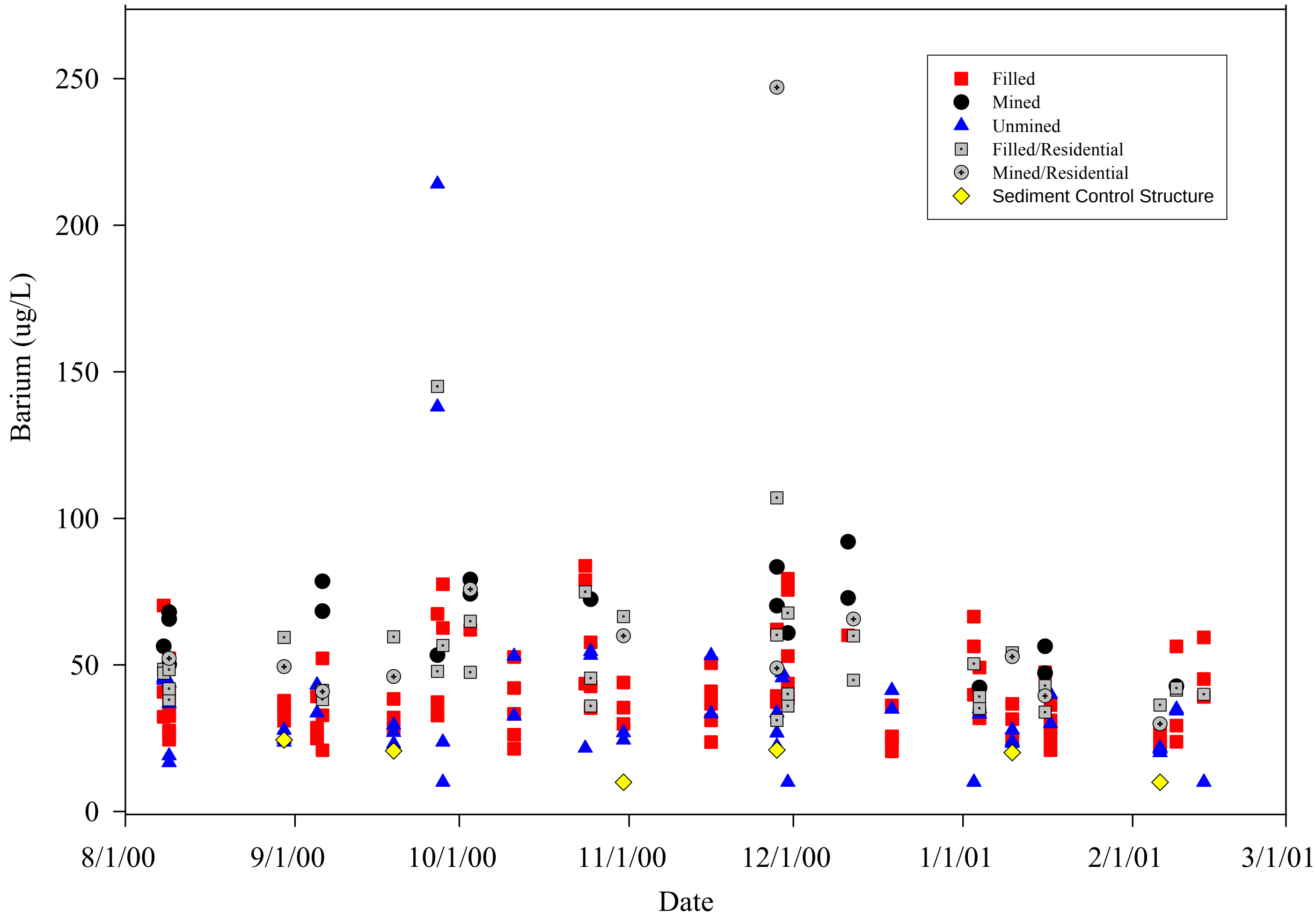
MT-13	Unmined	11/28/00	14.8	3.76	ND
MT-14	Filled	08/30/00	7.64	2.14	ND
MT-18	Filled	08/30/00	7.41	ND	ND
MT-23	Fill/Res	08/30/00 11/28/00	20.4 5.6	2.1 ND	ND ND
MT-24	Sediment Control Structure	08/30/00 09/19/00 10/31/00 11/28/00 01/10/01 02/06/01	8.15 ND 6.56 5.83 ND ND	ND ND ND ND ND ND	35.5 36.8 71.8 63.4 115 80.4
MT-39	Unmined	11/29/00	5.23	7.4	ND
MT-50	Unmined	08/09/00	ND	4.48	ND
MT-57B	Filled	08/09/00	ND	16.2	ND
MT-62	Fill/Res	09/06/00	ND	ND	37.6
MT-64	Filled	09/06/00	ND	ND	39.5
MT-69	Min/Res	11/28/00	6.72	ND	ND
MT-79	Mined	11/28/00 01/16/01	8.01 5.23	ND ND	ND ND
MT-81	Mined	11/28/00	ND	13.8	ND

5.17 Other Parameters Detected in Measurable Concentrations

5.17.a Total Barium

Barium was detected in 96 % of the 213 samples analyzed at the second laboratory. The detection limit was 20 ug/L. Concentrations are plotted in Figure Ba-1. They range to 250 ug/L but most values are below 75 ug/L. There were higher values on 9/27/00 and 11/28/00. The three samples in September were from MT-39 (138 ug/L), MT-40 (145 ug/L) and MT-42 (214 ug/L), all in the Spruce Fork watershed. Each concentration was two to three times the average for each site and flows were higher than average as well. A note on the field sheets for that day stated, “ Recent heavy rains have changed the stream bottom ...” Sites MT-39 and 42 are both Unmined. The data would indicate there was a temporary release of barium in these two tributary watersheds and in fact the decreasing concentration of barium at downstream site MT-48 (47.8 ug/L) would also fit that theory. Barium muds are used in drilling for oil and gas. The highest concentration at any site was detected 11/28/00 at site MT-01 (214 ug/L) in the headwaters of the Mud River. The next site downstream on the Mud, MT-23 also had a higher than normal concentration of barium area. (107ug/L). This appears to be another instance of a temporary release of barium in a headwater area.

Figure Ba-1. Concentration of Barium for All Sites vs. Date - Lab 2 Only

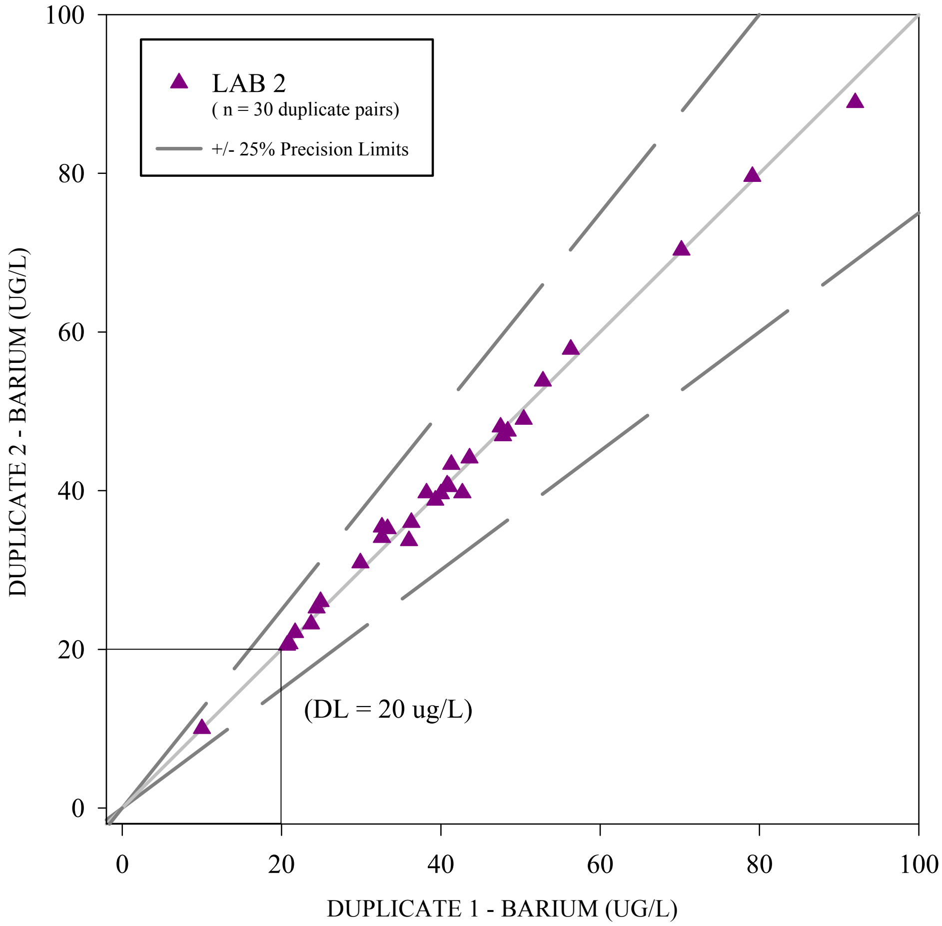


The only field note the crew made for that set of samples was for site MT-23 where they stated,"Beaverdam constructed downstream affecting depth and velocity flow measurements." The mix of categories of sites across the range of concentrations and over the study period have no obvious patterns. Some Unmined sites have an elevated barium concentration while the sediment control structure and some Filled sites consistently have low concentrations of barium.

Duplicate sample results are presented in Figure Ba-2. The data indicate excellent precision to roughly 100 ug/L (five times the detection limit).

There is no clear indication that MTM/VF mining changes the concentration of barium in streams.

Figure Ba-2. Comparison of Duplicate Samples - Barium - Lab 2 Only



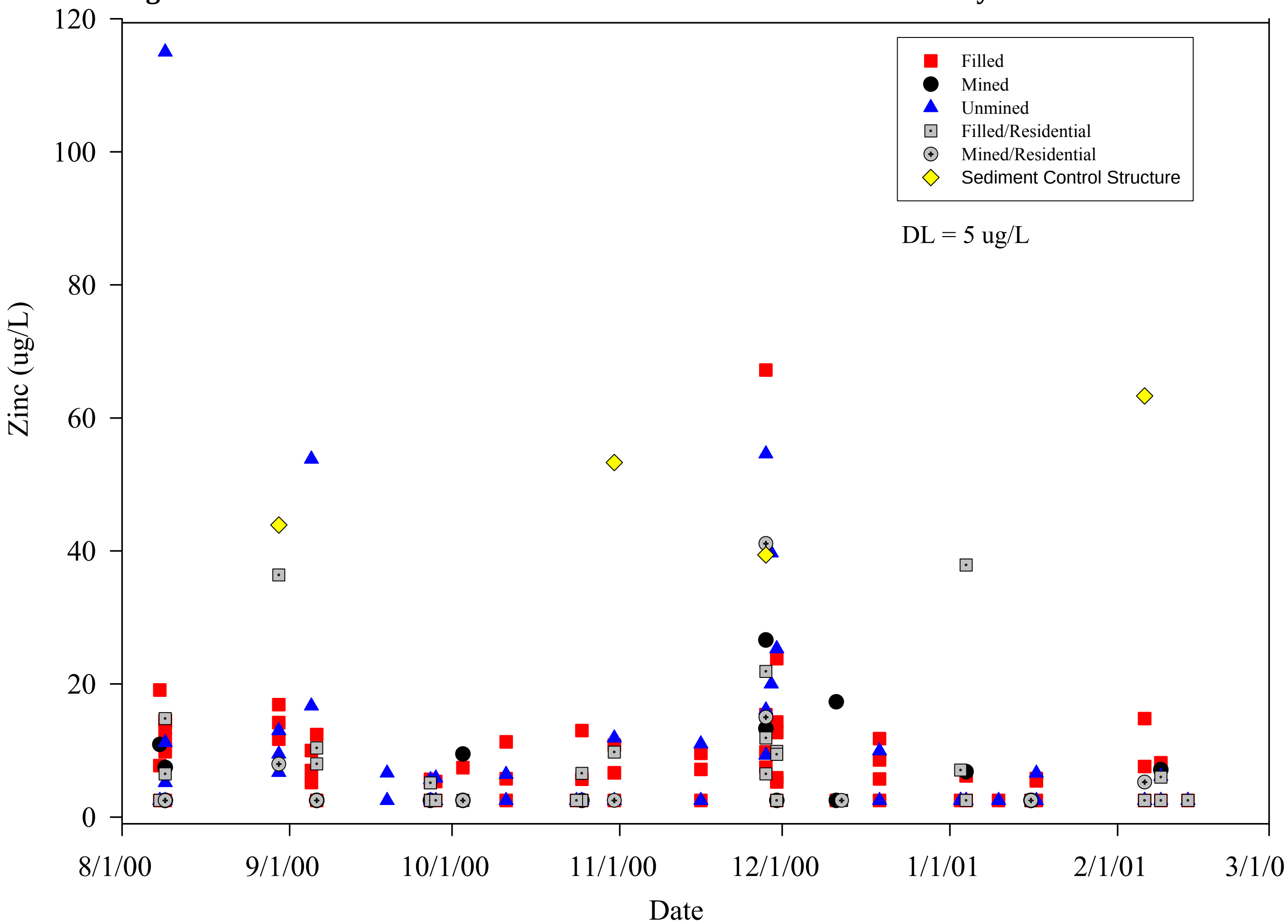
5.17.b Total Zinc

Zinc was detected in 51 % of the 199 samples that passed the QA/QC review and were analyzed in the second laboratory. The detection limit was 10 ug/L. The values are presented in Figure Zn-1.

Most values are below 20 ug/L where there was less precision in laboratory results. Zinc concentrations were elevated at MT-24, the Sediment Control Structure indicating that MTM/VF mining could cause elevated levels of zinc in streams, however there are also high values for zinc at four different Unmined sites (MT-50 on 8/9/00, MT-95 on 9/5/00, MT-13 on 11/28/00 and MT-39 on 11/29/00).

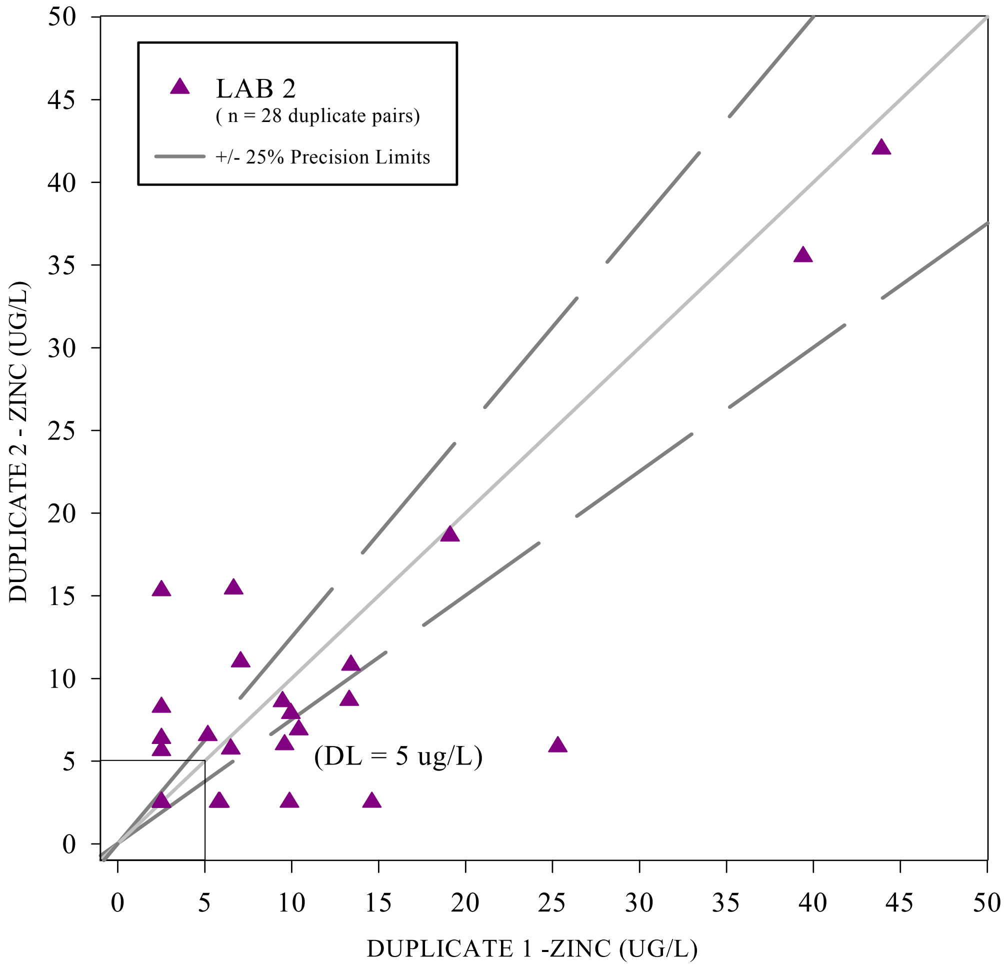
Duplicate sample results are presented in Figure Zn-2. The data indicate there were precision problems below a concentration of roughly 25 ug/L. Duplicate sample values range to roughly 45 ug/L which is 4.5 times the detection limit. Since most of the values from sites were below 25

Figure Zn-1. Concentration of Zinc for All Sites vs. Date - Lab 2 Only



ug/L where there was less precision, there is no clear indication that MTM/VF mining changes the concentration of zinc in streams.

Figure Zn-2. Comparison of Duplicate Samples - Zinc - Lab 2 Only



5.17.c Total Organic Carbon & Dissolved Organic Carbon

TOC and DOC results were generally very low near the detection limit of 1 mg/L. There was a confounding factor with the DOC test in that something appeared to be leaching from the filter used to remove the suspended matter in the field. The field crews used 45micron cellulose acetate membrane disposable sterile syringe filters. Whatever this interfering material was, it would create an organic value of up to 2 mg/L in some samples resulting in QA/QC flags on data. Of the 213 samples collected, 180 TOC values passed the QA/QC review and 170 DOC samples passed. TOC was detected in 77 % of the samples and DOC was detected in 86 % of the samples passing QA/QC review.

Figure TOC-1 plots the results of duplicate samples for TOC at the second laboratory. It illustrates the lack of precision in concentrations below about 2.5 mg/L. The range of duplicate sample values went to 3 mg/L. The maximum concentration of TOC recorded at the second laboratory was 4.4 mg/L. Only 14 (10%) of the 138 values detected were above 2.5 mg/L. Four of the 14 were at Unmined sites.

Figure TOC-1. Comparison of Duplicate Samples - Total Organic Carbon - Lab 2 Only

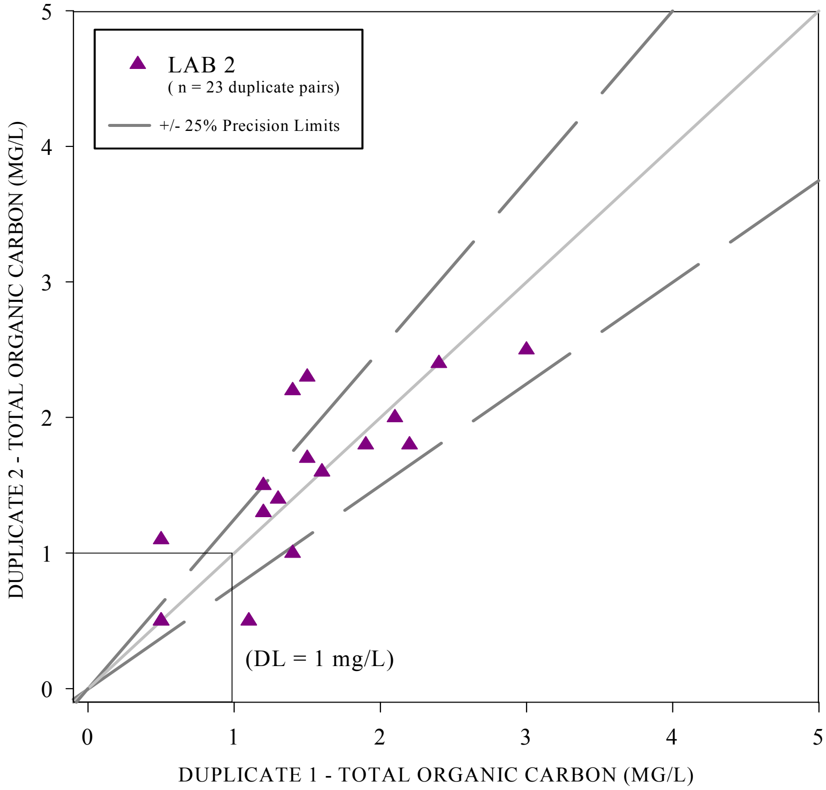


Figure DOC-1. Comparison of Duplicates - Dissolved Organic Carbon - Lab 2 Only

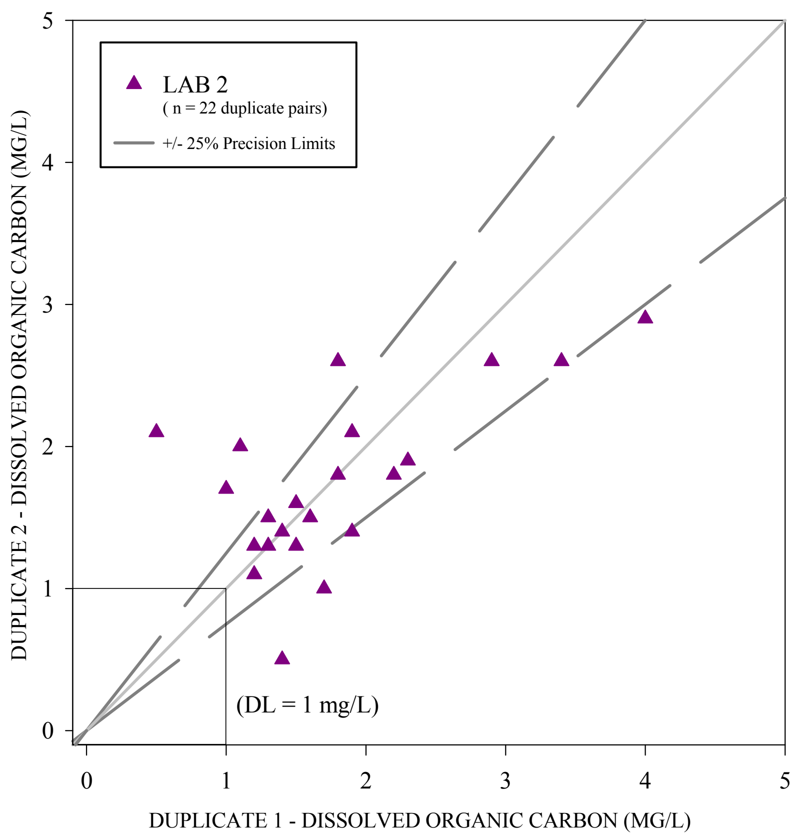


Figure DOC-1 plots the results of duplicate samples for DOC at the second laboratory. It also illustrates the lack of precision in concentrations for the range of values which went to about 4 mg/L. There is no clear indication that MTM/VF mining changes the concentration of TOC or DOC in streams.

5.17.d Total Suspended Solids

Coal mines have specially designed and constructed ditches and sedimentation ponds to reduce erosion and minimize the amount of suspended solids carried from a mine site in surface runoff. Large surface mine operations have elaborate systems required as part of their mining permits. Mine operators regularly monitor and maintain these facilities to capture sediment being washed from their mine site.

There were 213 samples for total suspended solids (TSS) analyzed at the second laboratory and none were rejected in the QA/QC review. A total of 69 of those samples (32 %) had concentrations at or above the detection limit of 5 mg/L. The values were low and this could be due to several factors including: dry fall weather; staff who chose not to sample on rainy days; because the sediment ponds below mined areas were working well; or other unknown causes. Whatever the cause, only 28 samples had a concentration above 10 mg/L. These values were from all categories of sites and are listed below. The data indicate that the concentration of TSS in the streams in the study area was usually below 5 mg/L during the study period.

Site Identification	**Category**	**Concentration (mg/L)**
MT-02	Unmined	19
MT-13	Unmined	24
MT-24	Sediment Control Ditch	21, 15, 14, 11
MT-34B	Filled	11
MT-42	Unmined	65, 12
MT-45	Mined	25
MT-48	Filled/Residences	20
MT-52	Filled	53
MT-55	Filled/Residences	51
MT-57B	Filled	11
MT-60	Filled	60, 25, 14
MT-62	Filled/Residences	20, 16
MT-64	Mined/Residences	32, 13, 12
MT-69	Mined/Residences	18
MT-75	Filled/Residences	19, 15
MT-79	Mined	14
MT-86	Filled	27
MT-91	Unmined	21

6. COMPARISON WITH APPLICABLE STREAM WATER QUALITY CRITERIA

The grab samples collected in this study are compared to the “not to exceed” limits set to protect aquatic life. A detailed description of West Virginia’s stream water quality criteria is included in Attachment 1. There are ten applicable parameters that have stream limits set to protect aquatic life and have a maximum or minimum limit. They will be discussed in alphabetical order.

Only the results from the second laboratory are included in this comparison. Laboratory results for metals were more precise at the second laboratory than at the first according to the data from duplicate samples. There were fewer instances of contaminated blank samples in the data from the second laboratory (see Table 3). There were far fewer laboratory results rejected in the QA/QC review at the second laboratory than at the first (see Table 5).

6.1 Total Aluminum - Maximum 750 ug/L

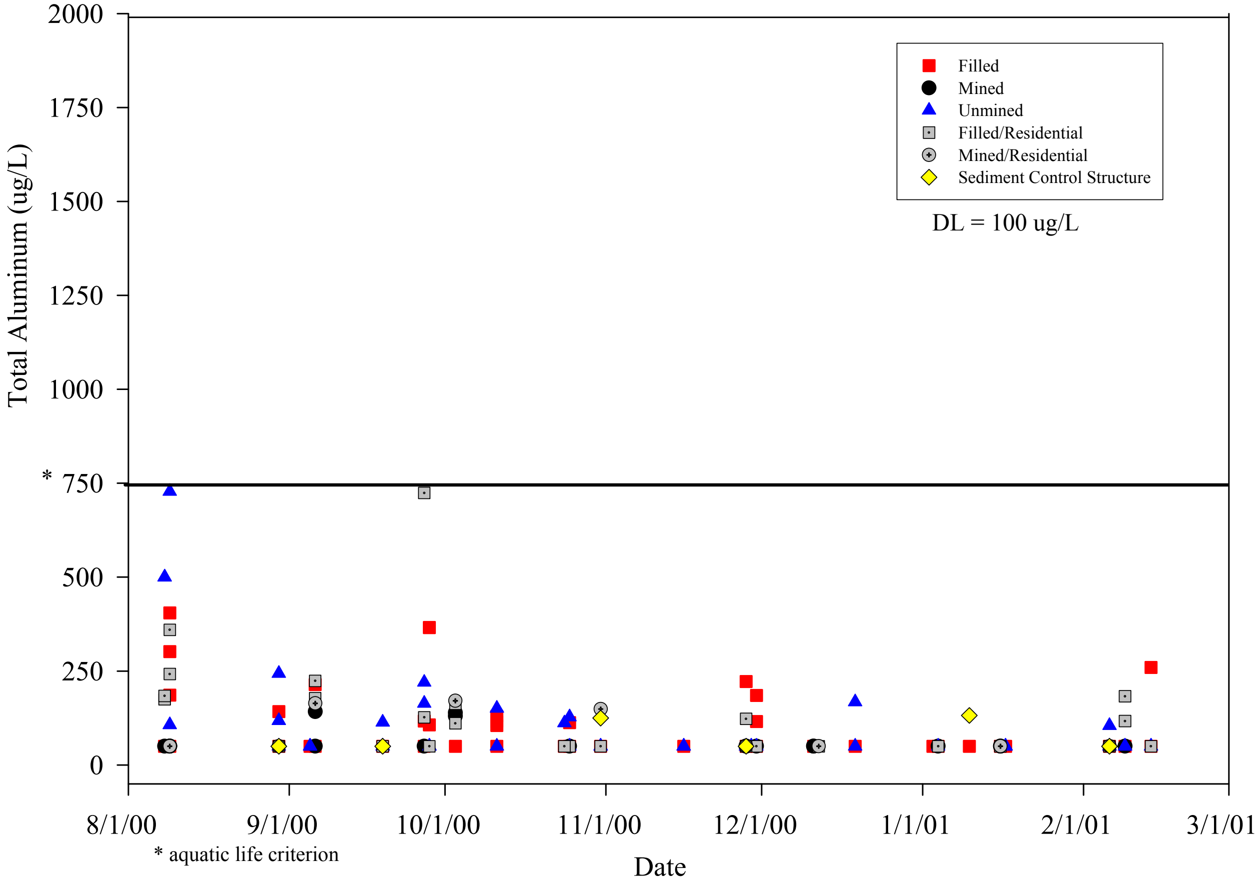
There were 213 samples for total aluminum sent to the second laboratory and one result was rejected in the QA/QC review resulting in 99.53 % completeness. The detection limit was 100 ug/L.

6.1.a Aluminum Concentration in Stream Samples

Aluminum was found in samples from all classes of sites and from sites spread across the study area but generally at concentrations below 250 ug/L. There were no sample results from the second laboratory that exceeded the stream criterion for aluminum Six samples collected 8/9/00 had higher concentrations of aluminum but they were flagged as estimates due to contamination of the blank The three values above 750 ug/L on that date are not considered as violations of the stream criterion since they were flagged as estimates.

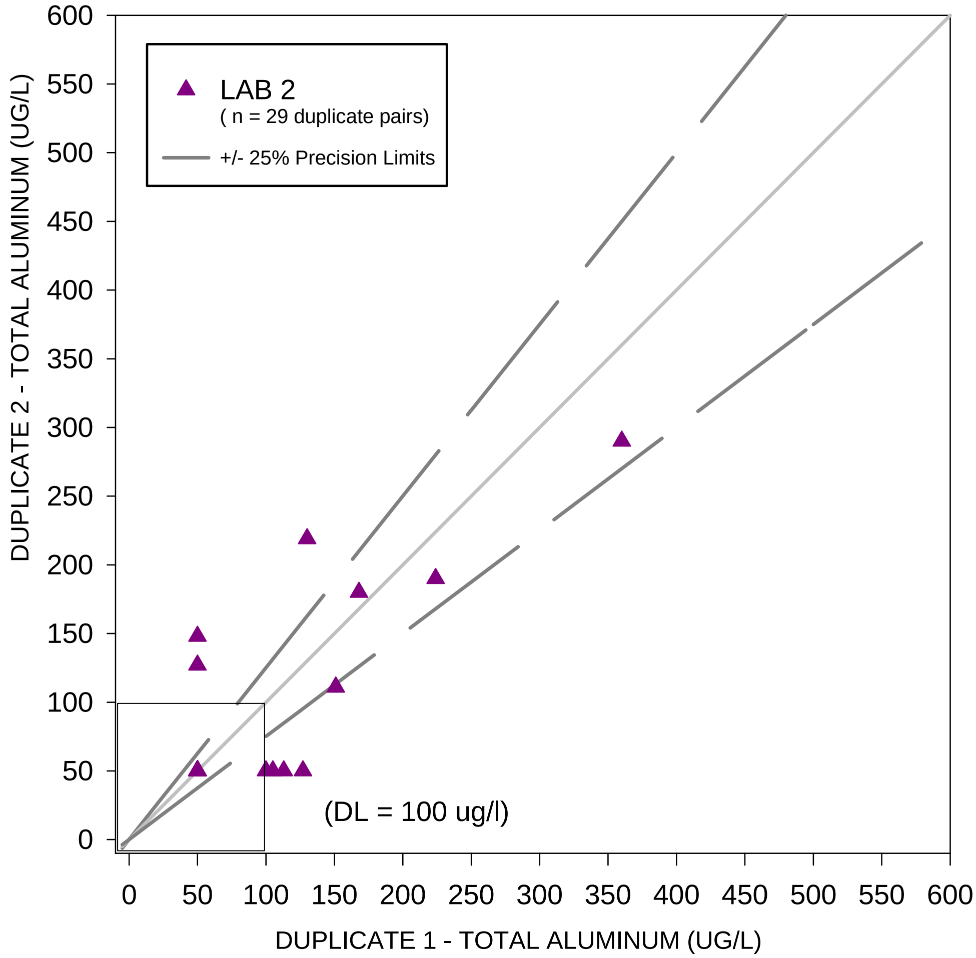
Figure Al-1 plots the concentration of aluminum for samples tested at the second laboratory. Most values are below 250 ug/L where there was less precision in duplicate sample results.

Figure Al-1. Total Aluminum Concentrations for All Site Categories vs. Date - Lab 2 Only



Duplicate sample results (29 pairs) are presented in Figure Al- 2. It is obvious from the Figure that the precision wavers a bit as the concentrations approach the detection limit. Forty-eight blank samples were tested and three were found to have detectable concentrations of aluminum. Two of those were near the detection limit. The high aluminum in one blank sample lead to having the data flagged as an estimate for that blank sample as well as the stream samples collected by that crew that day.

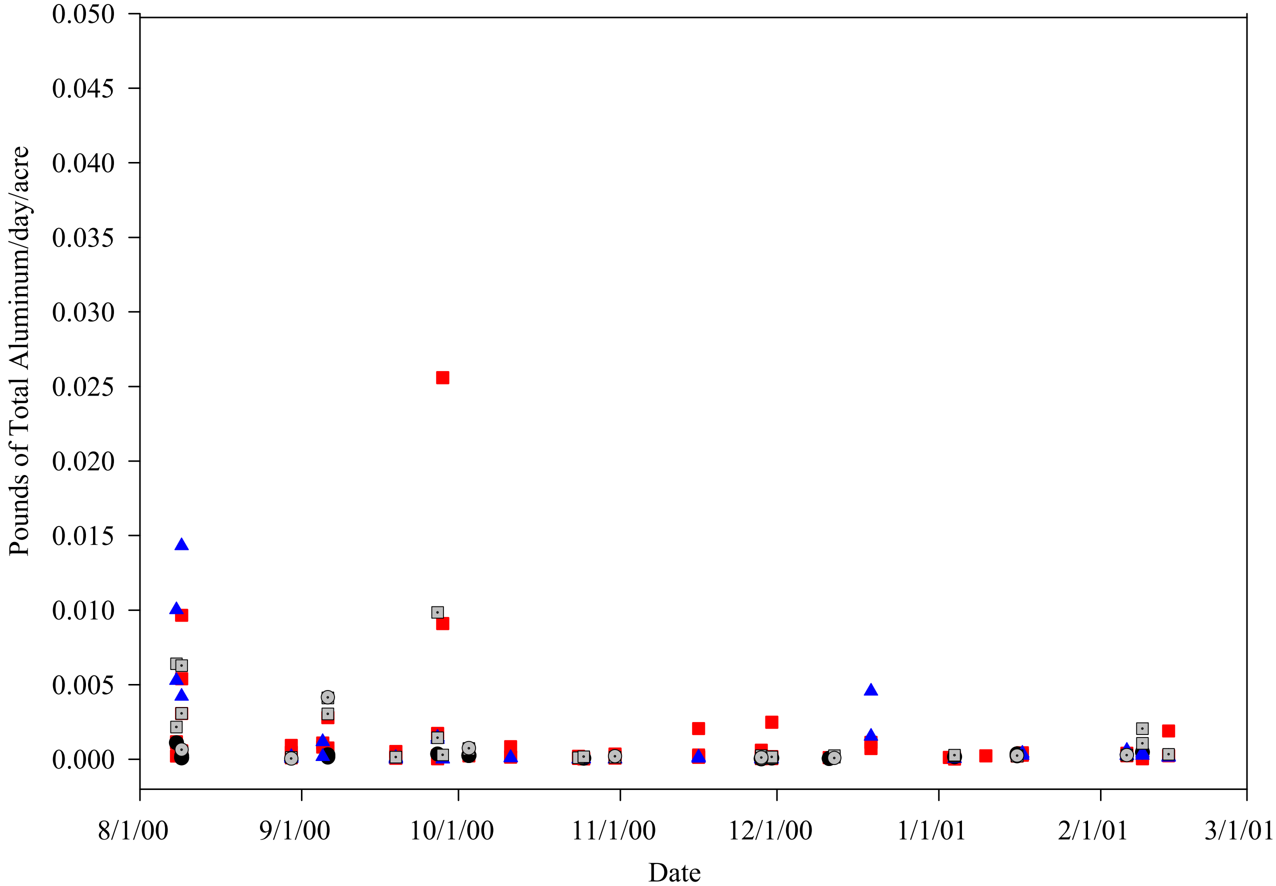
Figure Al-2. Comparison of Duplicate Samples - Total Aluminum - Lab 2 Only



6.1.b Aluminum Yield

The Yield values for total aluminum have been plotted vs date and are presented in Figure Al-3. Most yield rates are below 0.01 pounds per day per acre and there is no obvious pattern in the results. MTM/VF mining does not appear to produce a great difference in the Yield of aluminum within the study area.

Figure Al-3. Aluminum Yield for All Site Categories vs. Date - Lab 2 Only



6.1.c Dissolved Aluminum

Field crews filtered samples to check for dissolved aluminum. The second laboratory detected it in only five (2 %) of 213 samples with the maximum value being 129 ug/L. The values are listed below. Dissolved aluminum was detected in only one set of duplicate samples at the second laboratory at the detection limit of 100 ug/L. There is no clear indication that MTM/VF mining changes the concentration of dissolved aluminum in streams.

Site	**Category**	**Dissolved Aluminum (ug/L)**
MT-39	Unmined	121
MT-45	Mined	110
MT-69	Mined/Residences	100
MT-75	Filled/Residences	105
MT-79	Mined	129

6.2 Total Beryllium - Maximum 130 ug/L

The second laboratory analyzed 213 samples for beryllium in this study. The QA/QC review rejected none of those values resulting in 100 % completeness. Beryllium was not detected in any samples analyzed at the second laboratory. There was no detectable concentration of beryllium in any duplicate sample nor in any blank sample. There is no indication that MTM/VF mining changed the concentration of beryllium in streams in the study area.

6.3 Chloride - Maximum 230 mg/L

There were 213 samples analyzed for chloride by the second laboratory during this study. None were rejected in the QA/QC review resulting in 100 % completeness for the data set. The maximum concentration of chloride was 37.6 mg/L. The detection limit was 5 mg/L. None of the blank samples had detectable levels of chloride. There is no indication that MTM/VF mining caused any violation of WVDEP's stream water quality criterion for chloride during this study.

6.4 Dissolved Oxygen - Minimum 5.0 mg/L

Dissolved Oxygen is a field reading. There were 475 field readings for Dissolved Oxygen and 12 were rejected in the QA/QC review.The percent completeness in 97.47 %. Only 9 of the values were less than the minimum stream criterion of 5 mg/L, and they are listed below in Table DO-1. The minimum value recorded was 3.77 mg/L but all other values were in the 4 mg/L range. They were measured in June, August, or October. One was at an Unmined site, five were in Mined sites, and one each in Filled, Filled/Residence, and Mined/Residence.

TABLE DO-1
Samples Not Meeting Aquatic Life Minimum Criterion of 5.0 mg/L for Dissolved Oxygen

Station ID	EIS CLASS	SAMPLE DATE	VALUE (mg/L)
MT13	Unmined	10/26/99	3.77
MT79	Mined	06/13/00	4.09
MT79	Mined	08/09/00	4.12
MT78	Mined	08/09/00	4.25
MT81	Mined	06/13/00	4.37
MT81	Mined	08/09/00	4.38
MT75	Filled/Residences	06/13/00	4.47
MT69	Mined/Residences	06/13/00	4.66
MT64	Filled	06/13/00	4.88

WVDEP's stream criterion for Dissolved Oxygen was violated in only 2% of the samples in this study and those were in the seasons of summer and fall. There is no indication that MTM/VF mining caused violations of dissolved oxygen criteria in the study area.

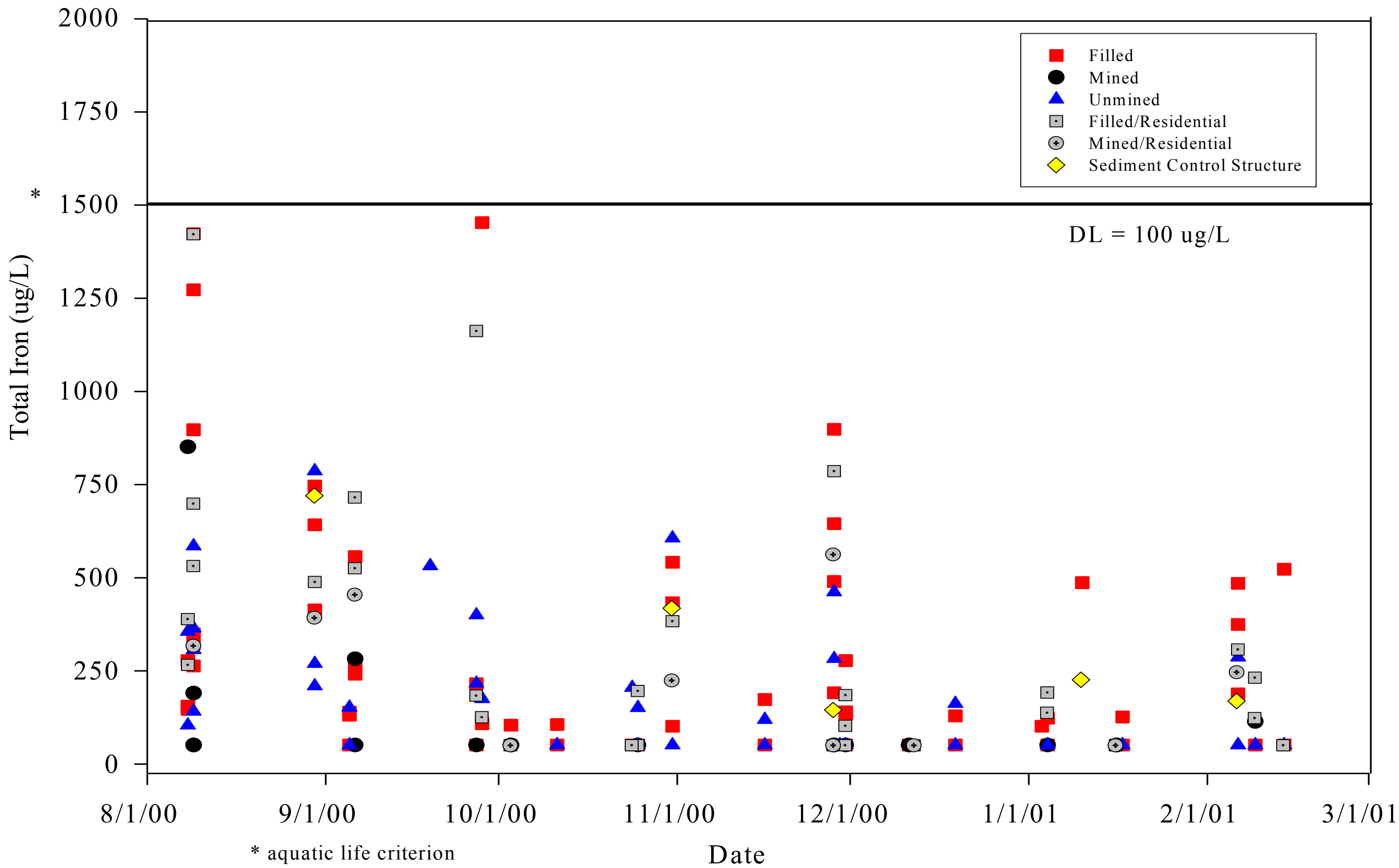
6.5 Total Iron - Maximum 1,500 ug/L

There were 213 samples analyzed for iron at the second laboratory and eight were rejected in the QA/QC review resulting in 96.24 % completeness. The detection limit was 100 ug/L.

6.5.a Iron Concentration in Stream Samples

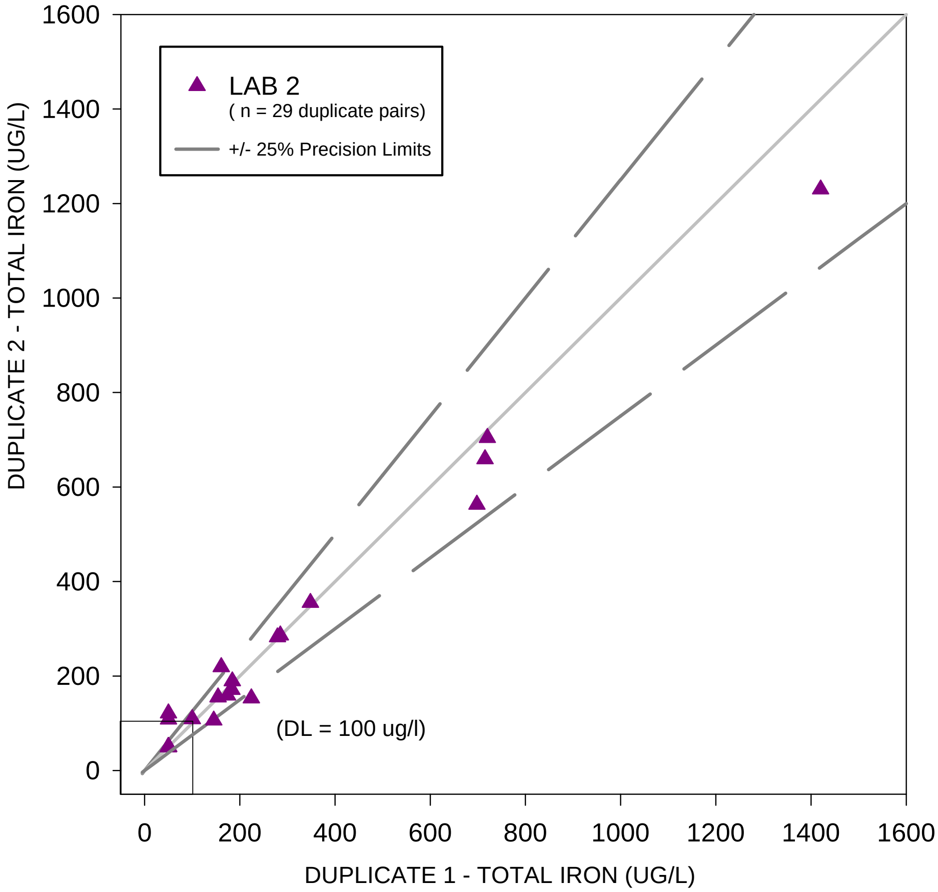
The iron concentration of each stream sample analyzed at the second laboratory during this study is presented in Figure Fe-1. The stream criterion of 1500 ug/L is indicated on the figure. There were no violations of the criterion for iron, but several samples from sites in the category Filled approached the limit during the fall of 2000. There is no clear indication that MTM/VF mining caused violations of the iron limit in streams in the study area.

Figure Fe-1. Total Iron Concentrations for All Sites vs. Date - Lab 2 Only



The results of duplicate samples are plotted in Figure Fe-2. The results are precise in the higher concentrations but waver as the concentration approached the detection limit. Only one of the 47 blank samples had a detectable concentration of iron.

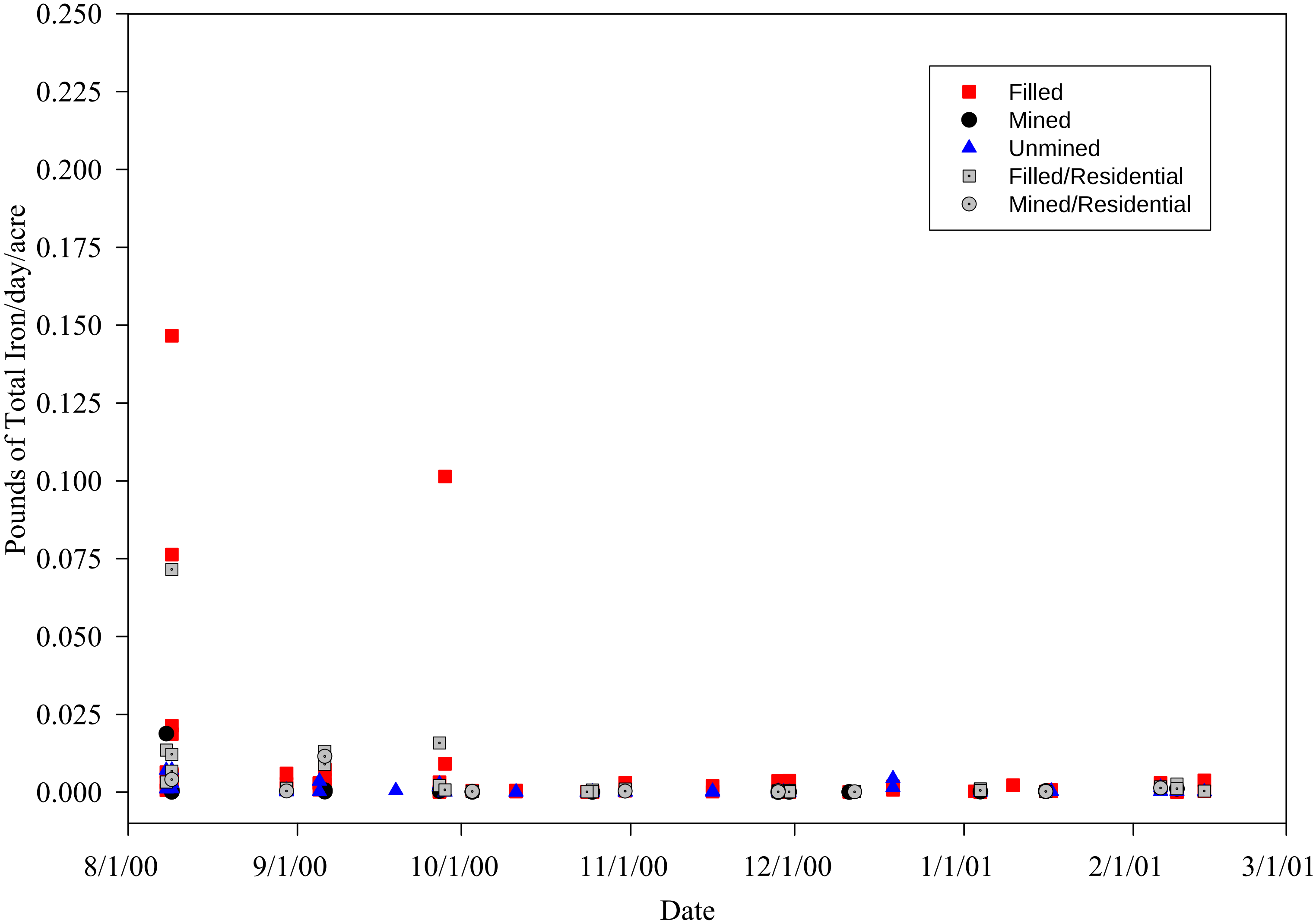
Figure Fe-2. Comparison of Duplicate Samples - Total Iron - Lab 2 Only



6.5.b Iron Yield

The Yield values for iron have been plotted vs date and are presented in Figure Fe-3. Although there are a couple higher values at Filled sites, most are values are below 0.01 pounds per day per acre. Variations in Yield rates for total iron could have several causes including changing amounts of suspended sediment that contains iron. The amount of suspended sediment in a stream is impacted by rainfall, ponds and vegetation cover on mine sites. The actual cause of the variation observed here is not known. There is no clear indication that MTM/VF mining changes Iron Yield in the study area.

Figure Fe-3. Iron Yield for All Sites vs. Date - Lab 2 Only



6.5.c Dissolved Iron

Dissolved iron was filtered in the field and 208 samples analyzed at the second laboratory passed the QA/QC review. A total of 33 samples (16 %) had values above the detection limit of 100 ug/L. Four of those samples came from two sites in the "Unmined" category while twenty-one of the samples came from nine sites in the "Filled" category. The "Filled" site MT-18 had dissolved iron on each sampling occasion ranging from a low of 200 ug/L to a high of 490 ug/L. The adjacent "Filled" site MT-14 had five detectable values from 110 ug/L to 483 ug/L. The other seven "Filled" sites had detectable concentrations of dissolved iron on only one or two occasions. Some "Filled" sites have persistent dissolved iron up to 480 ug/L and some "Unmined" sites have intermittent dissolved iron up to 390 ug/L.

6.6 Total Mercury - Maximum 2.4 ug/L

There were 213 samples analyzed for mercury at the second laboratory and 174 values passed the QA/QC review. The percent completeness is 81.69 %. None of the samples had a detectable concentration of mercury. The detection limit was 0.2 ug/L. No stream samples results exceeded the stream criterion of 2.4 ug/L. There is no indication that MTM/VF mining activities cause a measurable increase in the concentration of mercury in streams in the study area.

6.7 pH - Minimum 6.0, Maximum 9.0

There were pH measurements made in the field and the laboratory in this study, but only the field values are valid in evaluating compliance with stream limits. All 476 records of field pH in this study have been judged valid so the data set completeness is 100 %. Only three of those values fell outside of the limits of 6.0 to 9.0 set by the WVDEP. All three were for Unmined sites. This could be a result of acid deposition but that is not known for sure. The sites are:

Table pH - 1. Samples Not Meeting pH Criteria - 6.0 to 9.0

Station ID	EIS Category	Sample Date	Value
MT-03	Unmined	11/28/00	5.87
MT-13	Unmined	11/28/00	5.44
MT-50	Unmined	08/09/00	5.79

There were no violations of stream pH criteria resulting from MTM/VF mining identified during this study.

6.8 Total Selenium

There were 213 samples analyzed for selenium in the second laboratory for this study. The QA/QC review rejected three values resulting in 98.59 % completeness. The detection limit was 3 ug/L at the second laboratory.

Selenium is essential for life in very small amounts but is highly toxic in slightly greater amounts (Lemly 1996, page 427). In 1987, the EPA lowered the recommended stream water quality criterion for selenium to 5 ug/L to protect aquatic life. West Virginia has adopted that same limit as their stream criterion. Selenium is strongly bioaccumulated in aquatic habitats (Lemly 1996, page 435). "Waterborne concentrations in the low-ug/l range can bioaccumulate in the food-chain and result in an elevated dietary selenium intake and the reproductive failure of adult fish with little or no additional symptoms of selenium poisoning in the entire aquatic system. .... The most widespread human-caused sources of selenium mobilization and introduction into aquatic ecosystems in the U.S. today are the extraction and utilization of coal for generation of electric power and the irrigation of high-selenium soils for agricultural production" (Lemly 1996, page 437).

The West Virginia Geologic and Economic Survey has information on selenium posted on their website (http;//www.wvgs.wvnet.edu/www/datastat/te/SeHome.htm). It notes:

> Selenium occurs in coal primarily within host minerals, most within commonly occurring pyrite...... An unpublished study at WVGES using SEM found selenium ... in 12 of 24 coal samples studied, mainly in the upper Kanawha Formation coals. .... Selenium in West Virginia coals averaged 4.20 ppm...... Coals containing the highest selenium contents are in a region of south central WV where Allegheny and upper Kanawha coals containing the most selenium are mined.... Selenium is not an environmental problem in moist regions like the Eastern U.S. where concentrations average 0.2 ppm in normal soils.

Summarizing this information, we see that in the region MTM/VF mining, the coals can contain an average of 4 ppm of selenium, normal soils can average 0.2 ppm, and the allowable limits in the streams are 5 ug/L (0.005 ppm). Disturbing coal and soils during MTM/VF mining could be expected to result in violations of the stream limit for selenium.

6.8.a Selenium Concentration in Stream Samples

Laboratory results for selenium from the second laboratory are shown in Figure Se-1. There are 66 violations of the stream criterion. All values above the stream criterion of 5 ug/L are at Filled sites and many of those are several times greater than the detection limit of 3 ug/L. The elevated values of selenium appear to be closely related to MTM/VF mining activity.
There were 30 sets of duplicate samples for selenium tested in the second laboratory. One set of duplicate samples was rejected in the QA/QC review. Figure Se-2 plots the results of duplicate samples. The precision of results of the duplicate samples at the second laboratory indicate that data can be used to identify violations of the stream criterion for selenium.

Figure Se-1. Selenium Concentrations at All Sites vs. Date - Lab 2 Data Only

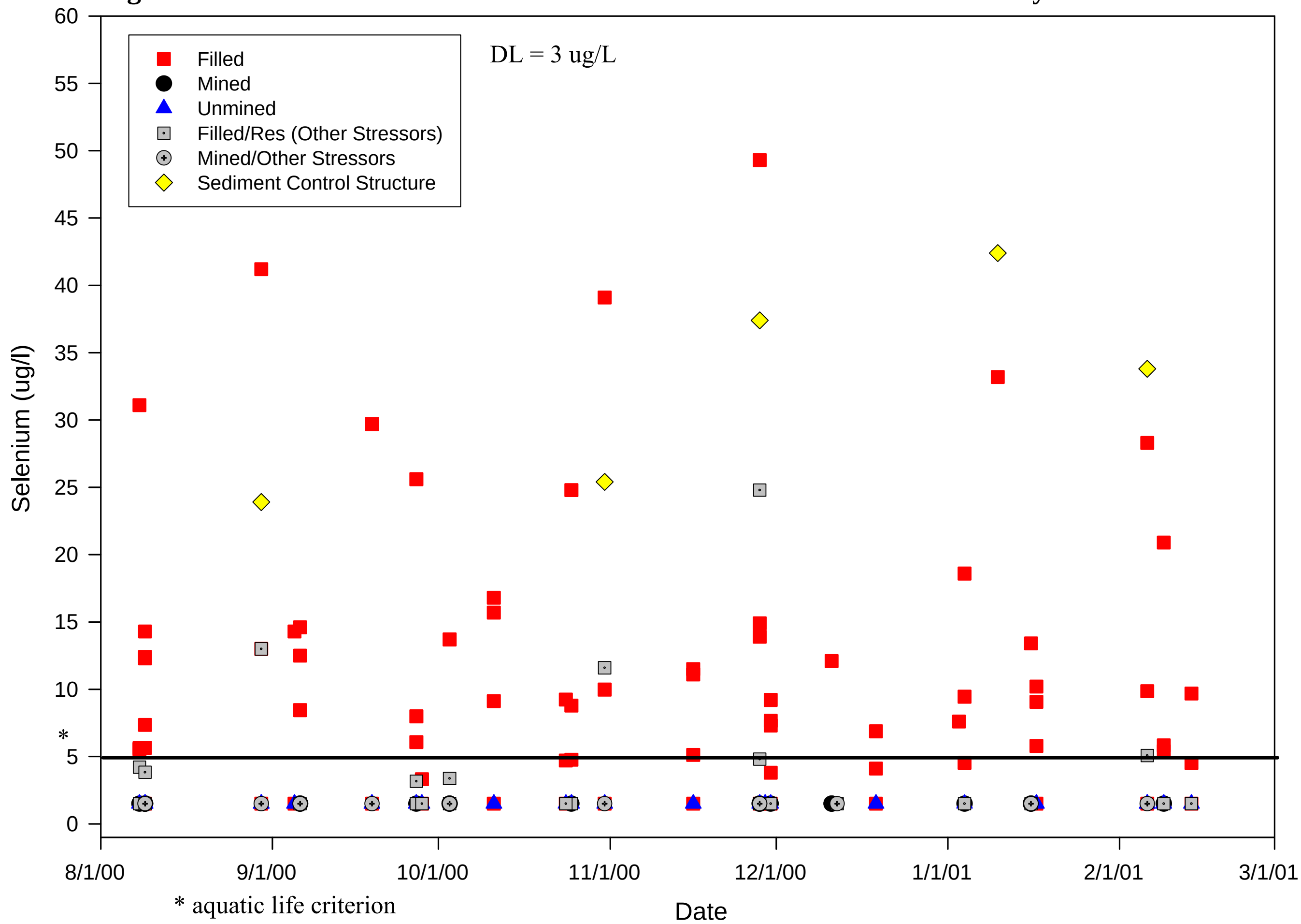
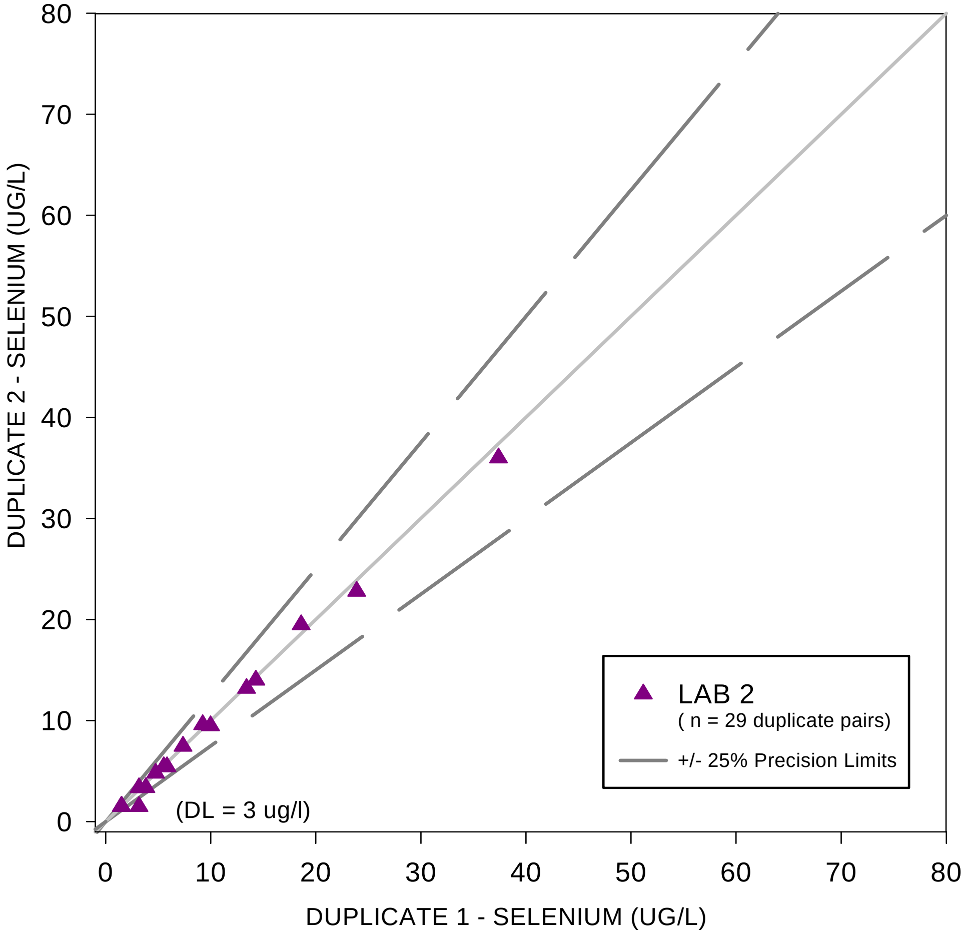


Figure Se-2. Comparison of Duplicate Samples Total Selenium - Lab 2 Only

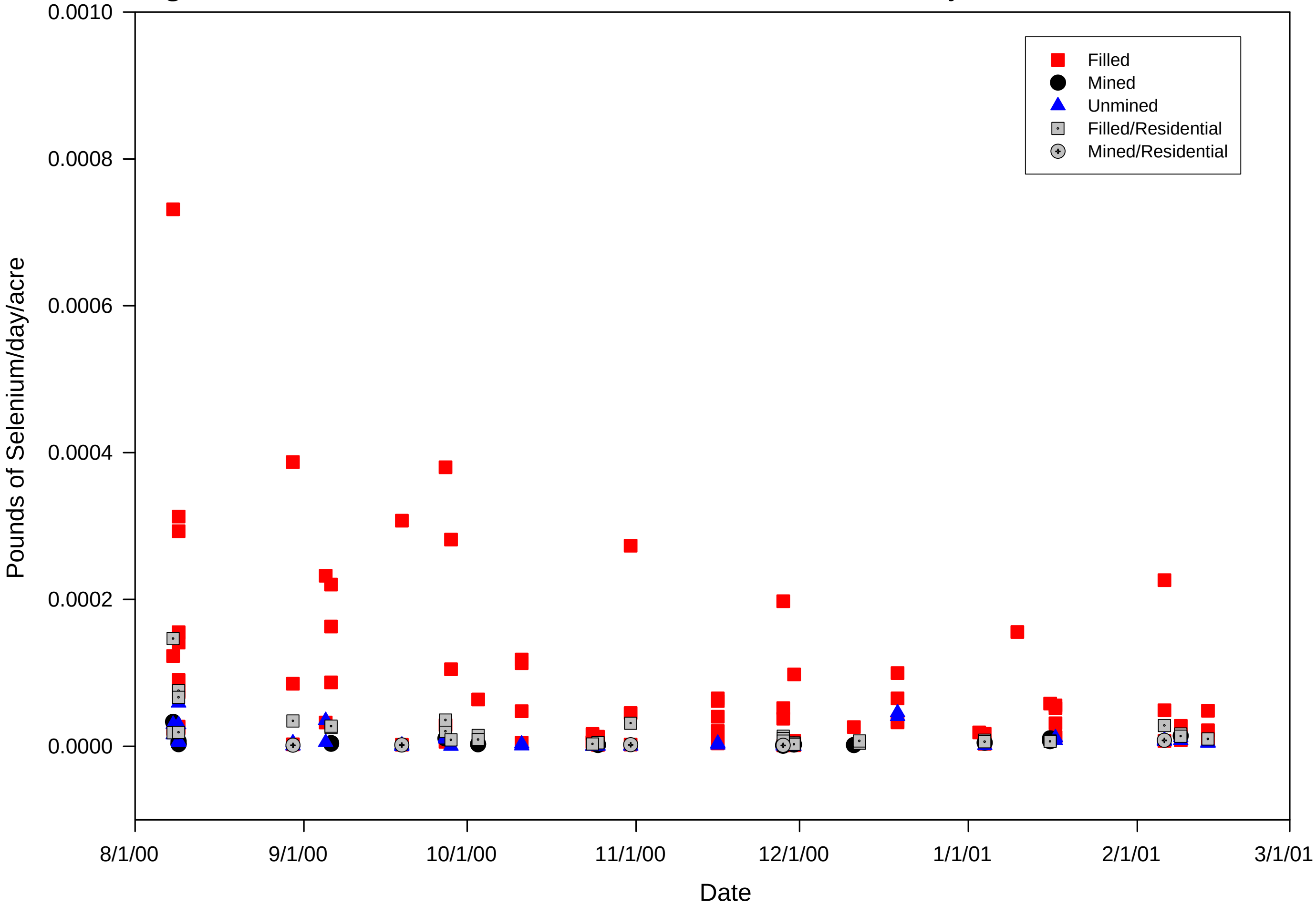


Accuracy was evaluated using spiked duplicates samples prepared in the laboratory and reviewed in the QA/QC review. Only one of the 50 blank samples tested in the second laboratory had a detectable concentration of selenium. The selenium dataset from the second laboratory is suitable for evaluating violations of the stream criterion of 5 ug/L.

6.8.b Selenium Yield

The Yield of selenium for all site samples is presented in Figure Se-3. The very low Yield rates for selenium are evident in the Figure. As noted earlier, even very small amounts of selenium in coals and soils can leach or erode to streams and exceed the water quality criterion. The Yield rates in sites exceeding the criterion were as low as 0.0002 pound per day per acre.

Figure Se-3. Selenium Yield for All Sites vs. Date - Lab 2 Data Only



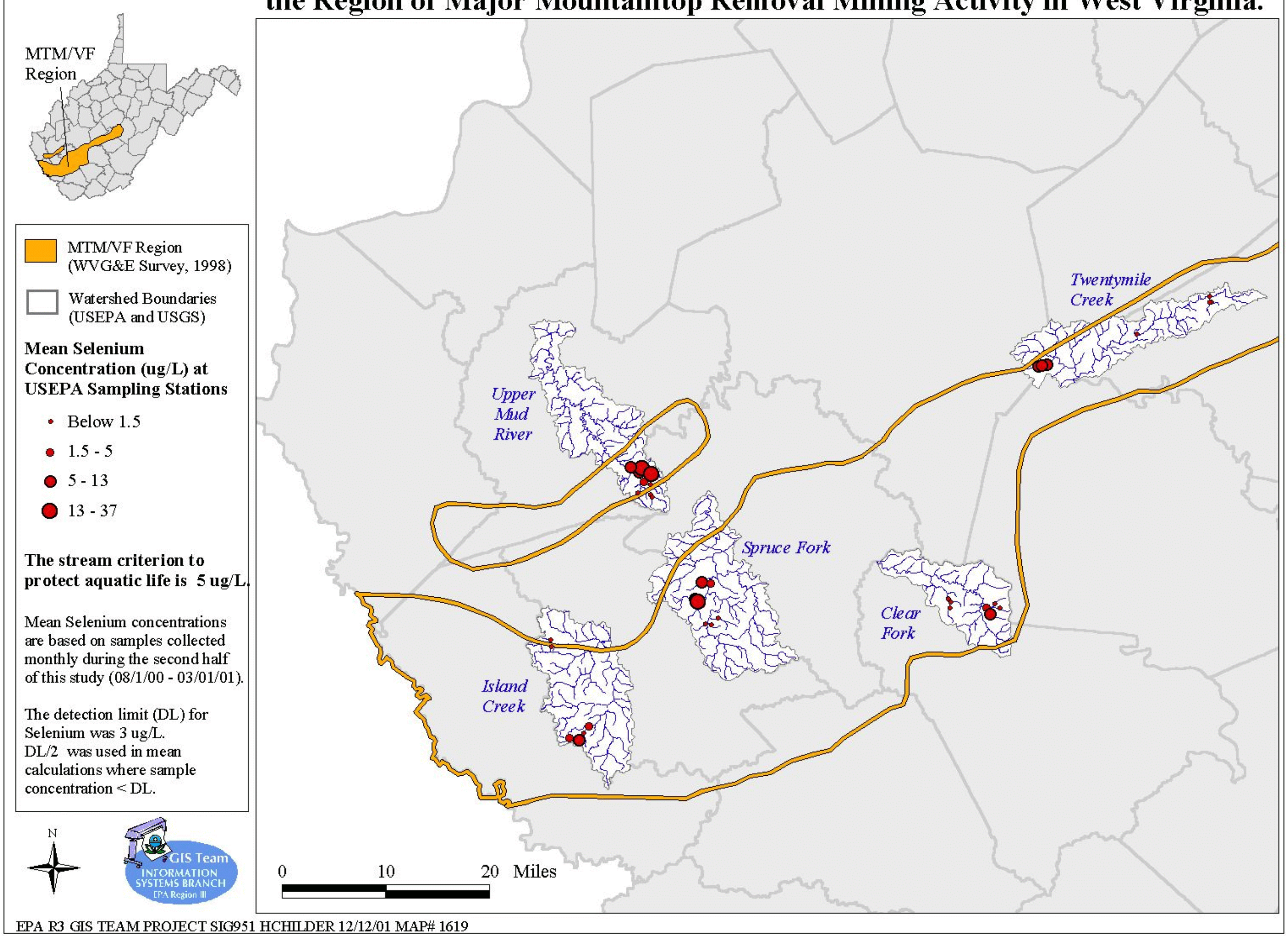
6.8.c Distribution of Sites Violating the Stream Criterion - Lab 2 Only

It was noted earlier that **66 violations of the stream criterion for selenium were identified in samples tested at the second laboratory**. The period of sampling began in August 2000 and ran through February 2001. Each site was visited six times in this period and samples were collected at each site if there was flow in the stream. There were 13 sites with selenium concentrations above the criterion and all are in the Filled category. Sites MT- 18, 32, 34B, 64, 98, and 103 exceeded the criterion in all six samples. Sites MT- 15, 23, 24, 57B, and 104 exceeded the criterion in five of the six samples. Sites MT-25B and 52 exceeded the criterion in two of the six samples.

The **average selenium concentration** for each site in the study was calculated for the last six months of the study and plotted on maps to better evaluate the distribution of the sites with high selenium. Figures Se-4 through Se-9 are maps of the study area showing the locations of the sites and the mean concentration of selenium reported by the second laboratory. Many sites had no detectable (N.D.) concentration of selenium reported by the laboratory, but that does not necessarily mean they have zero selenium. The laboratory's detection limit (DL) for selenium was 3 ug/L. In **calculating statistics for a site**, all samples having a reported concentration of N.D. were arbitrarily assigned a value of one half the D.L. or 1.5 ug/L. If the mean selenium concentration for a site is 1.5 ug/L, then all the values were below the detection limit. This is indicated on the maps by "Below D.L."

Figure Se-4 is a map of the entire study area which plots the locations of sites with a high median value for selenium concentrations. All violations of the criterion were at Filled sites. The sites with high selenium are scattered across the entire region of mountaintop mining, but within each watershed they seem be clustered in only a portion of the study area. Maps for each watershed were prepared to show the location and average concentration of selenium at the monitoring sites.

Figure Se-4. Mean Selenium Concentrations for USEPA Stream Sampling Stations within the Region of Major Mountaintop Removal Mining Activity in West Virginia.



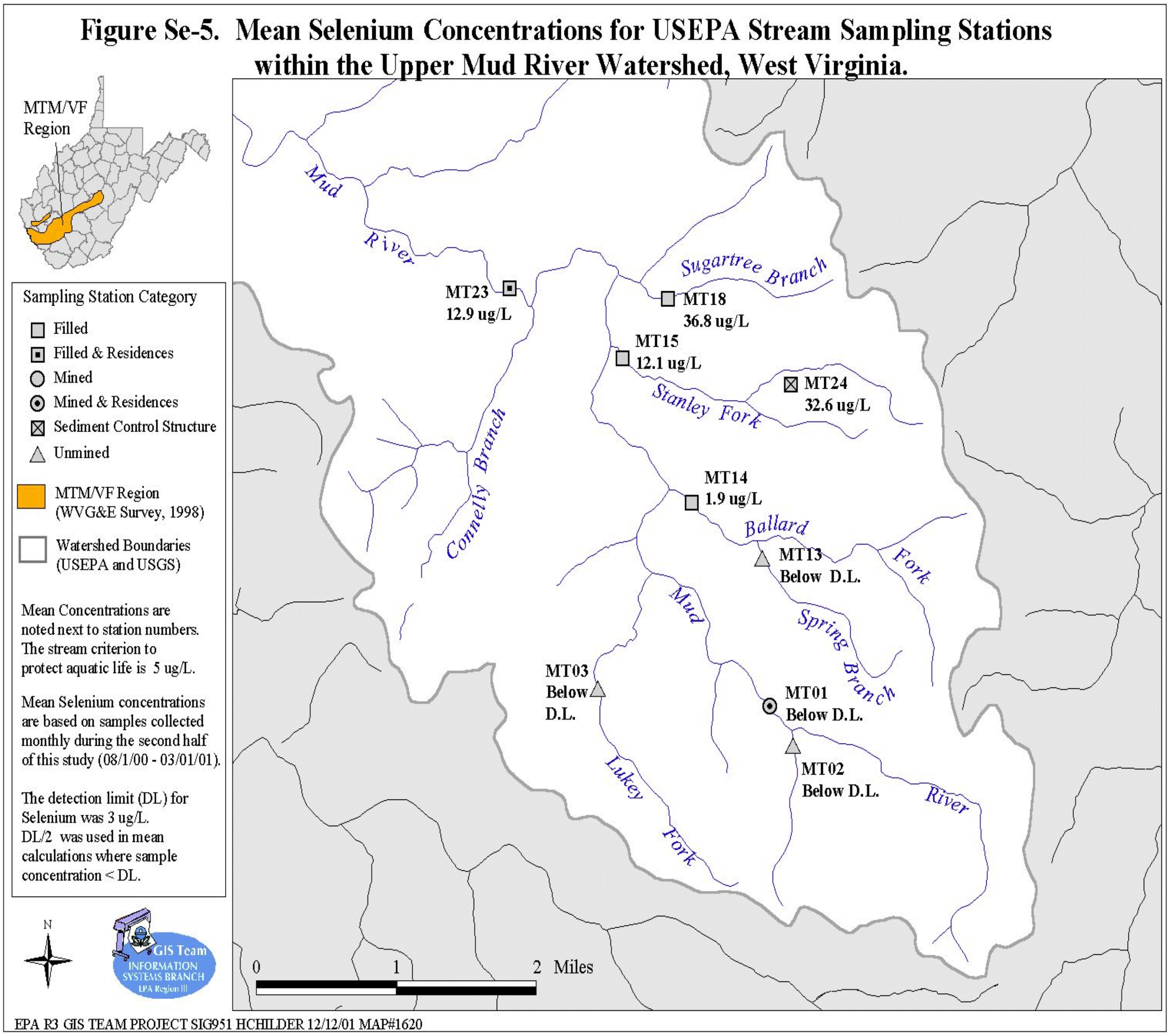


Figure Se-5. Mean Selenium Concentrations for USEPA Stream Sampling Stations within the Upper Mud River Watershed, West Virginia.

Figure Se-5 covers the Upper Mud River Watershed. Site MT-24 is actually in a diversion ditch on a reclaimed MTM/VF mine. Site information is:

Site ID	# of Fills /Year of Permit #	Average Selenium (ug/L)	Watershed (acres)
MT-14	8 / 1985, 88, 89	1.9	1,527
MT-15	6 / 1988, 89, 91, 92, 95	12.1	1,114
MT-18	2 / 1992, 95	36.8	479
MT-23	26 / 1985, 88, 89, 91, 92, 95, 96	12.9	10,618
MT-24	1 / 1988, 89	32.6	unknown

The level of selenium upstream other upstream sites MT-01, 02, 03, and 13 were all below the detection limit of 3 ug/L. There is a source of selenium in the upper portion of Sugartree Branch and Stanley Fork where there has been MTM/VF mining activity.

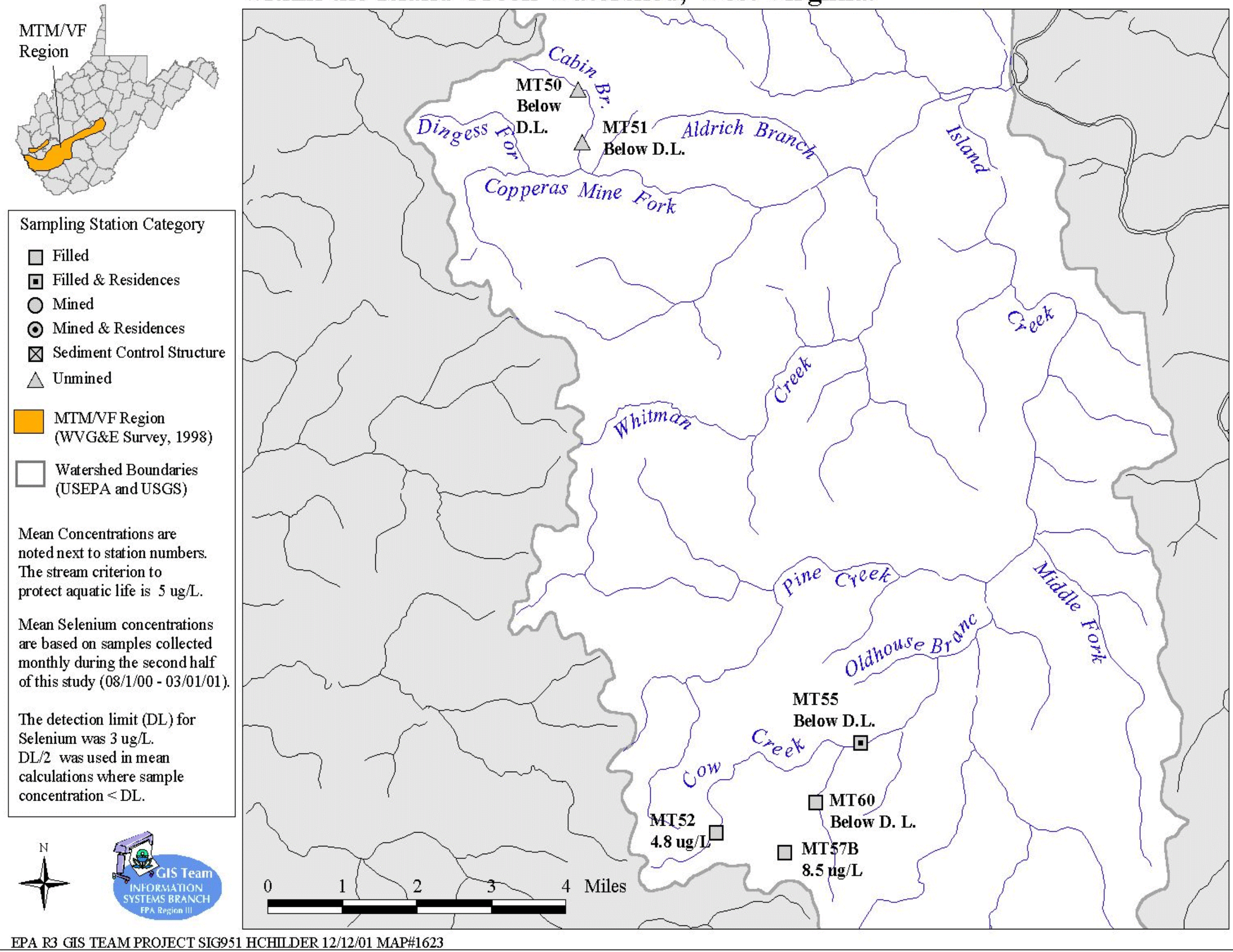


Figure Se-6. Mean Selenium Concentrations for USEPA Stream Sampling Stations within the Island Creek Watershed, West Virginia.

Figure Se-6 shows the average concentrations at the sites in the Island Creek watershed. In the Island Creek watershed there were two adjacent tributaries that exceeded the selenium criterion. The average value at MT-52 was 4.8 ug/L, and next door was MT-57B with an average of 8.5 ug/L. These values are near the detection limit of 3 ug/L. There was no detectable concentration of selenium downstream at MY-55 or MT-60. Dilution and the lack of additional sources of selenium could cause this. The other sites in this watershed (MT-50 & 51) had no detectable selenium. There appears to be a source of selenium in the upper portion of Cow Creek watershed where there has been MTM/VF mining activity.

Figure Se-7. Mean Selenium Concentrations for USEPA Stream Sampling Stations within the Spruce Fork Watershed, West Virginia.

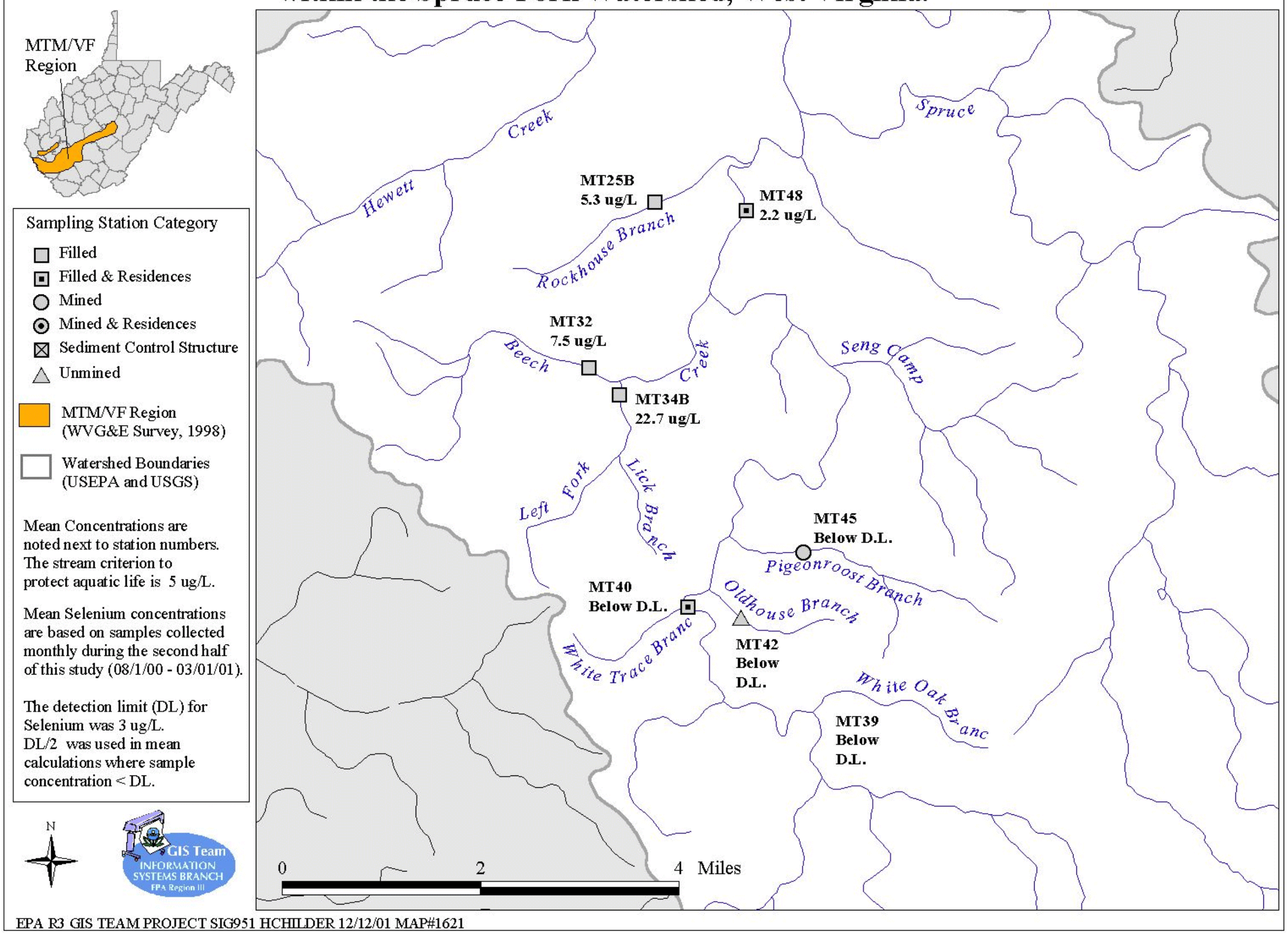


Figure Se-7 covers the sites within the Spruce Fork watershed. There were three sites on tributaries with fills in the Spruce Fork watershed that exceeded the criterion. Data on those sites is listed below:

Site ID	# of Fills /Year of Permit #	Average Selenium (ug/L)	Watershed (acres)
MT-25B	1 / 1986	5.3	997
MT-32	5 / 1986, 88, 89, 91	7.5	2,878
MT-34B	- / 1985, 86	22.7	1,677
MT-48	22 / many + 4 communities	2.2	27,742

There was no detectable concentration at the four other sites to the south in this watershed (MT-39, 40, 42, 45). There is a source of selenium in the upper portion of Beech Creek above MT-32 and MT-34B and in Rockhouse Branch above MT-25B where there has been MTM/VF mining activity.

Figure Se-8. Mean Selenium Concentrations for USEPA Stream Sampling Stations within the Clear Fork Watershed, West Virginia.

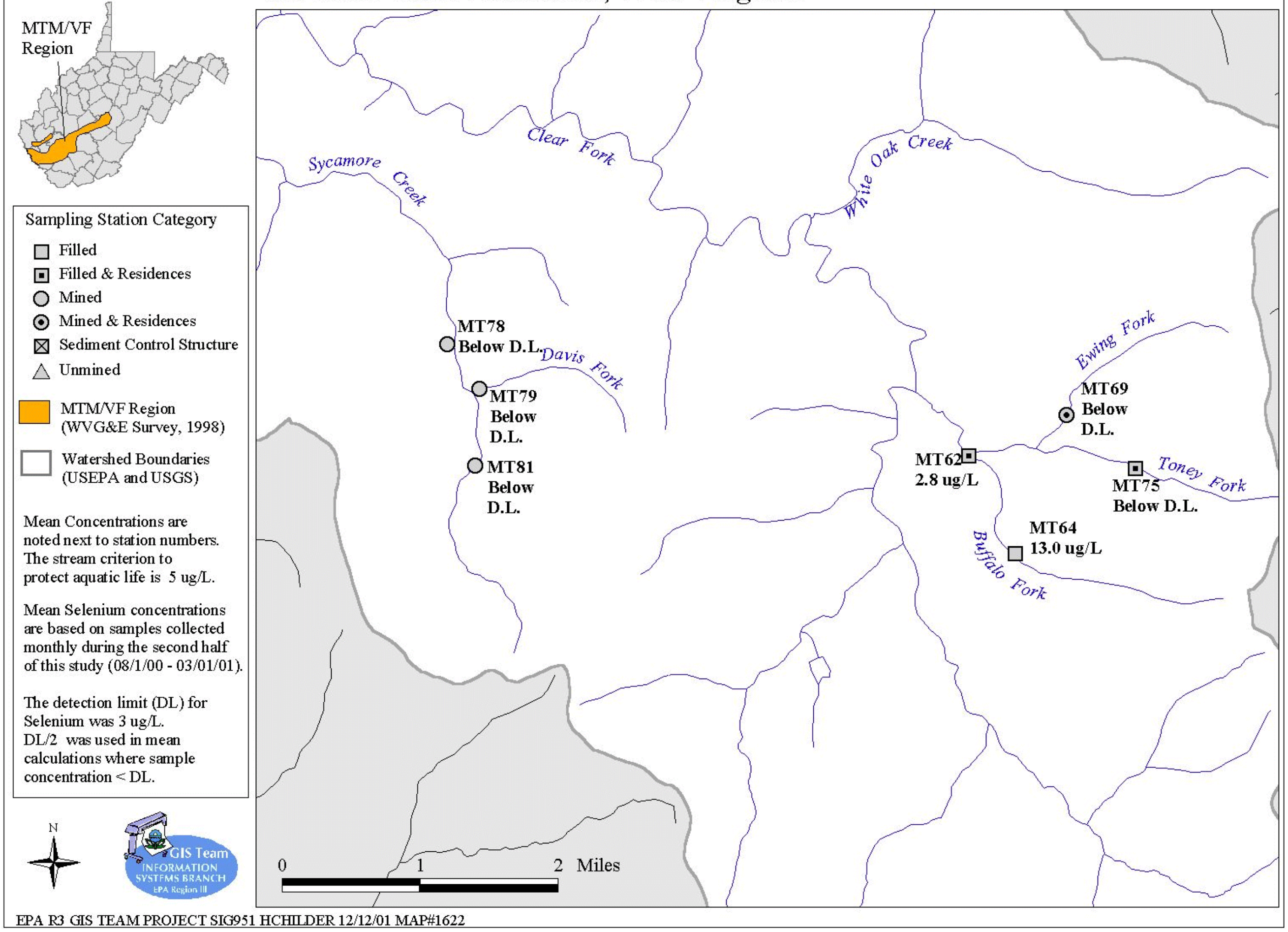


Figure Se-8 covers the sites within the Clear Fork watershed. Two sites in this watershed had measurable concentrations of selenium and data on them is listed below:

Site ID	# of Fills /Year of Permit #	Average Selenium (ug/L)	Watershed (acres)
MT-62	11 / 1989, 91, 92, 93	2.8	3,193
MT-64	5 / 1992, 93	13.0	758

The three other sites on Sycamore Creek (MT-78, 79, and 81) had no detectable concentration of selenium. There is a source of selenium in the upper portion of Buffalo Fork above MT-64 where there has been MTM/VF mining activity.

Figure Se-9. Mean Selenium Concentrations for USEPA Stream Sampling Stations within the Twentymile Creek Watershed, West Virginia.

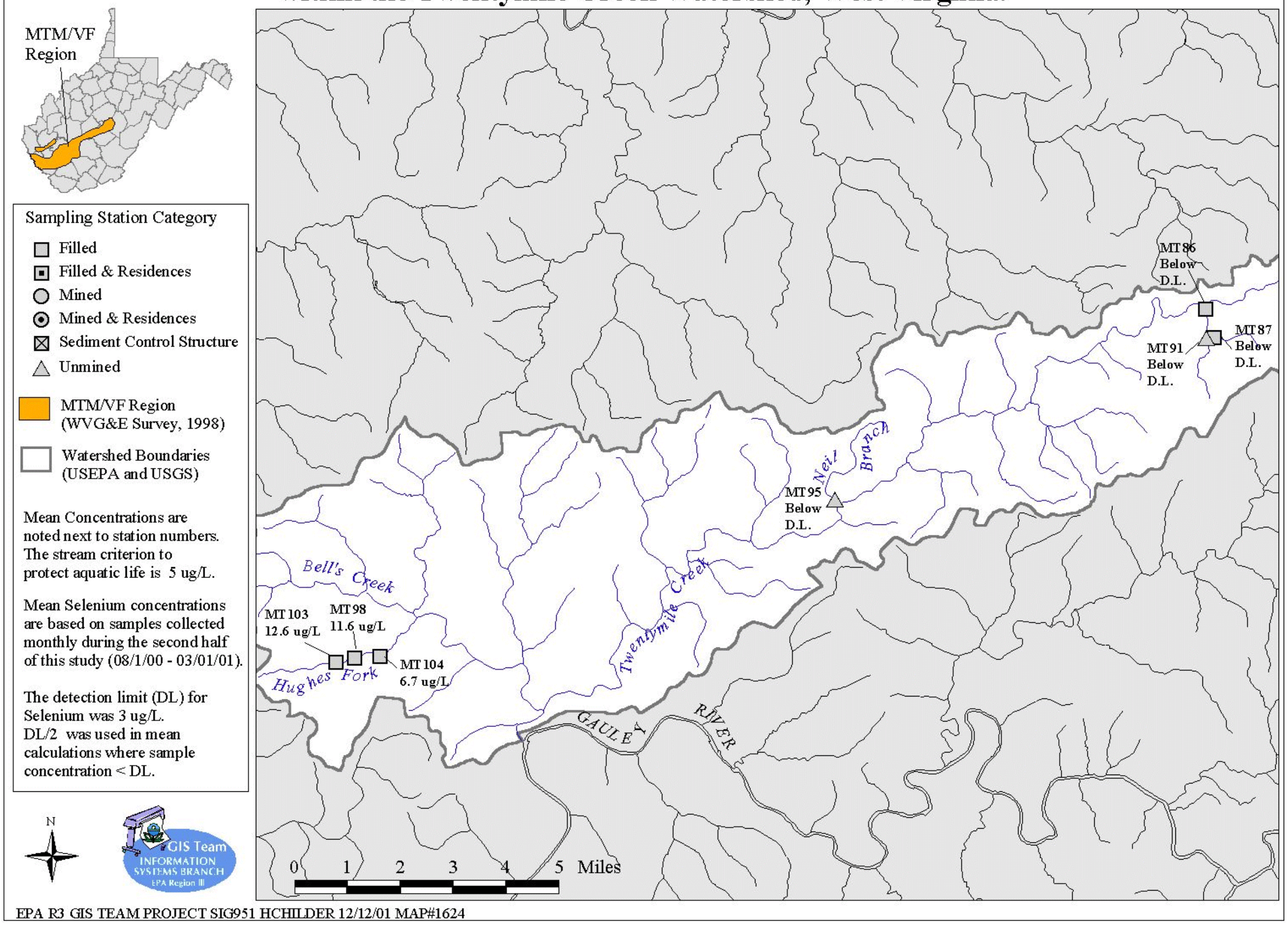


Figure Se-9 covers the sites within the Twentymile Creek watershed. The three sites in Twentymile Creek watershed that had excessive selenium are located along Hughes Fork and each one flows to the next. Data on the sites is listed below:

Site ID	# of Fills /Year of Permit #	Average Selenium (ug/L)	Watershed (acres)
MT-98	8 / 1977, 82, 90	11.6	1,208
MT-103	6 / 1977, 82, 90	12.6	1,027
MT-104	8 / 1977, 82, 90	6.7	2,455

The fact that the values get lower going downstream would indicate the effects of dilution and that there are no significant additional sources of selenium in this reach of stream. All other sites in the Twentymile watershed had no detectable concentrations of selenium. There is a source of selenium in the upper portion of Hughes Fork above MT-103 where there has been MTM/VF mining activity. It would be worthwhile to further evaluate what other common attributes, in addition to MTM/VF mining, exist among these sites. Those sites are: MT-18, MT-24, MT-25B, MT-32, MT-34B, MT-52, MT-57B, MT-64, MT-103.

6.9 Total Silver - Maximum Depends on Hardness

There were 213 samples analyzed for silver at the second laboratory. None were rejected in the QA/QC review so the percent completeness is 100 %. The detection limit was 10 ug/L. The second laboratory found no detectable concentration of silver in any duplicates or blanks or stream samples. MTM/VF mining does not appear to cause increased concentrations of silver to be released to streams in the study area.

6.10 Temperature - Maximum 87ºF May through November or 73ºF December through April

Temperature is a field measurement. There were 474 field measurements of stream temperature in this study. None of them exceeded the maximum allowable temperatures for West Virginia streams. Continuous temperature records, especially during the hotter summer months, would have been a better indicator of temperature.

7. OTHER EVALUATIONS

7.1 Parameters with Concentrations Below Detection Limits

In addition to total beryllium, total silver, and total mercury, there were eight other parameters which were not detected in any of the samples in this study reported in data from the second laboratory.

7.1.a Hot Acidity

The second laboratory tested for hot acidity in a few samples at the start of their contract work. The Study Plan called for only acidity, not hot acidity. Acidity was analyzed for all samples in this study and that data is discussed earlier in this report. There were 22 samples analyzed for hot acidity and none was detected in any sample. This limited amount of data on hot acidity does not support any conclusions.

7.1.b Total Antimony, Arsenic, Cadmium, Chromium, Cobalt, Thallium and Vanadium

There were 213 samples analyzed for these metals and none was detected in any sample at the detection limit of 5 ug/L. None of the blanks had detectable concentrations and all of the data passed the QA/QC review. MTM/VF mining did not impact the concentration of these metals in streams in the study area.

7.2 Flow Rate Data

The flow rate was measured 466 times when the stream was sampled in this study. There is a flow rate to go with 97.3% of the samples. Most flow rates were measured using standard stream gaging procedures and calculations. There has been considerable discussion and speculation regarding the impacts of MTM/VF mining on stream flows.

MTM/VF mining can affect runoff. Rain falling on a watershed either runs off in the stream or infiltrates into the ground. If it infiltrates, it either percolates through the rocks and eventually comes out of a spring that feeds a surface stream, or it is taken up by plants and stored or evaporated back into the atmosphere. Many aspects of MTM/VF mining activities can affect stream flow including: removing the trees and other plants; fracturing rocks; moving soil and rocks; constructing flow diversion channels and sedimentation ponds; constructing haul roads; reshaping and compacting mine spoil; constructing valley fills; and reestablishing vegetation on the mined area. MTM/VF activities can increase the base flows of streams while decreasing the peak flows of floods by temporarily storing the rainfall in ponds or in the increased voids in the spoil of mined areas. The Kentucky Geological Survey report *Hydrogeology, Hydrogeochemistry, and Spoil Settlement at a Large Mine-Spoil Area in Eastern Kentucky: Star Fire Tract* notes:

> Field investigations have identified numerous ground-water recharge and discharge zones at the mine spoil area. Recharge occurs by way of disappearing streams, ground-water infiltration along exposed boulder zones, and at areas where spoil is in contact with bedrock highwalls. Minor recharge occurs locally on the spoil's surface through macropores (snakeholes). Discharge of ground-water from the spoil occurs mainly through springs and seeps at the outslope of the spoil body. Ground-water movement within the spoil is controlled by the ground-water gradients within the spoil, which are a function of the buried topography and interaction of the recharge and discharge zones of low-permeability spoil. The spoil interior, lacking any major direct recharge from the surface, slowly accumulates water, whereas in the valley fills ground water moves at a rapid rate. Recharge to the valley fills comes from streams, adjacent bedrock aquifers, and from surface water that seeps in near the bedrock-spoil interface. (Wunsch 1996, page 25)

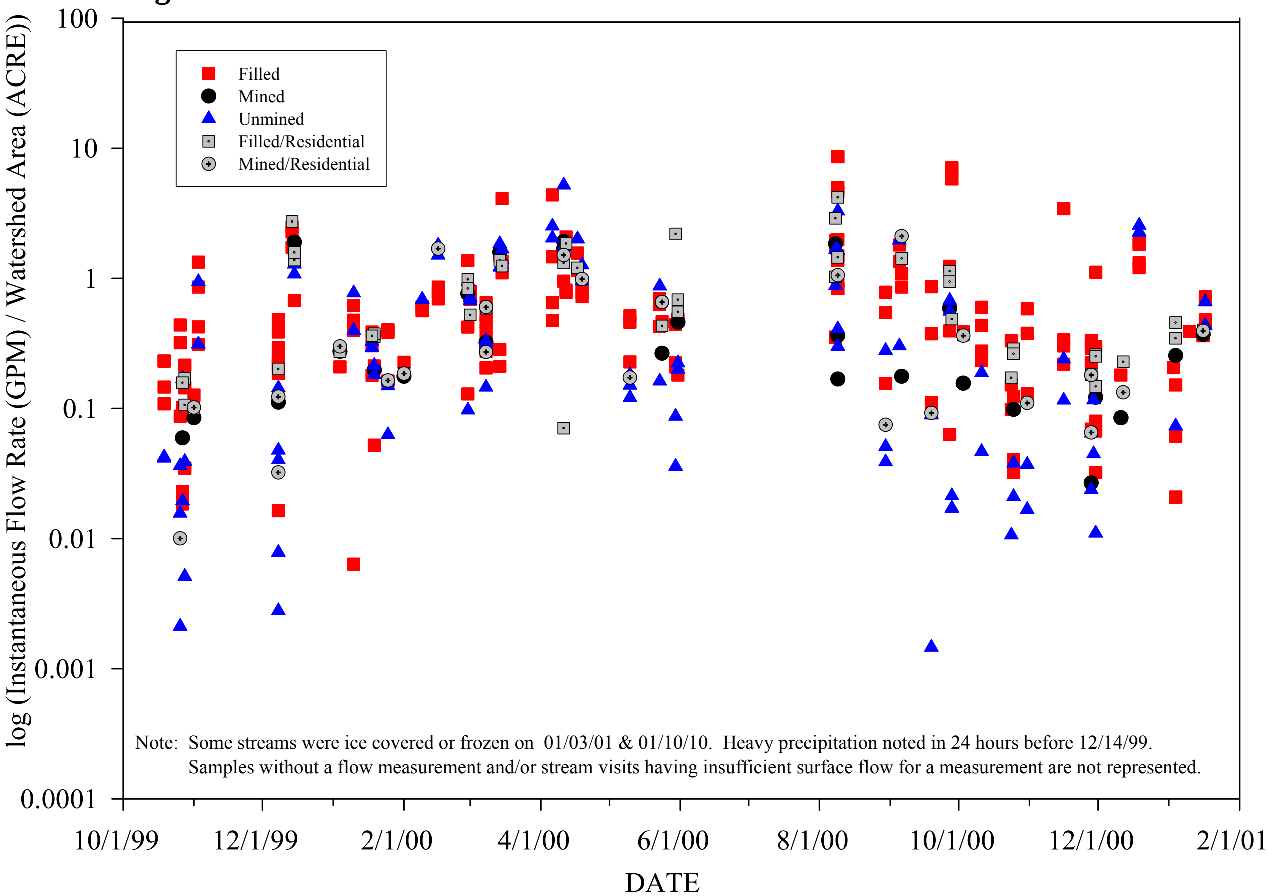
The impact of fills on base flow in streams has been investigated by several researchers. The USGS Water- Resources Investigations Report 01-4092, *Reconnaissance of Stream Geomorphology, Low Streamflow, and Mountaintop Coal-Mining Region, Southern West Virginia, 1999-2000* notes:

> ... the valley-fill sites can have about a 6-7 times greater 90-percent flow duration than unmined sites. (Wiley et al 2001, page 13)

The 90-percent flow duration is the flow that is exceeded 90 % of the time. The report indicates

that base flows of streams with valley fills are 6 to 7 times greater than the base flows of unmined areas.   Stream water quality below MTM/VF mines is also altered in base flow periods when the mineralized ground-water from the mined area becomes the major portion of the stream flow.
Figure Flow-1 plots the log of the normalized flow rate (the instantaneous flow divided by the

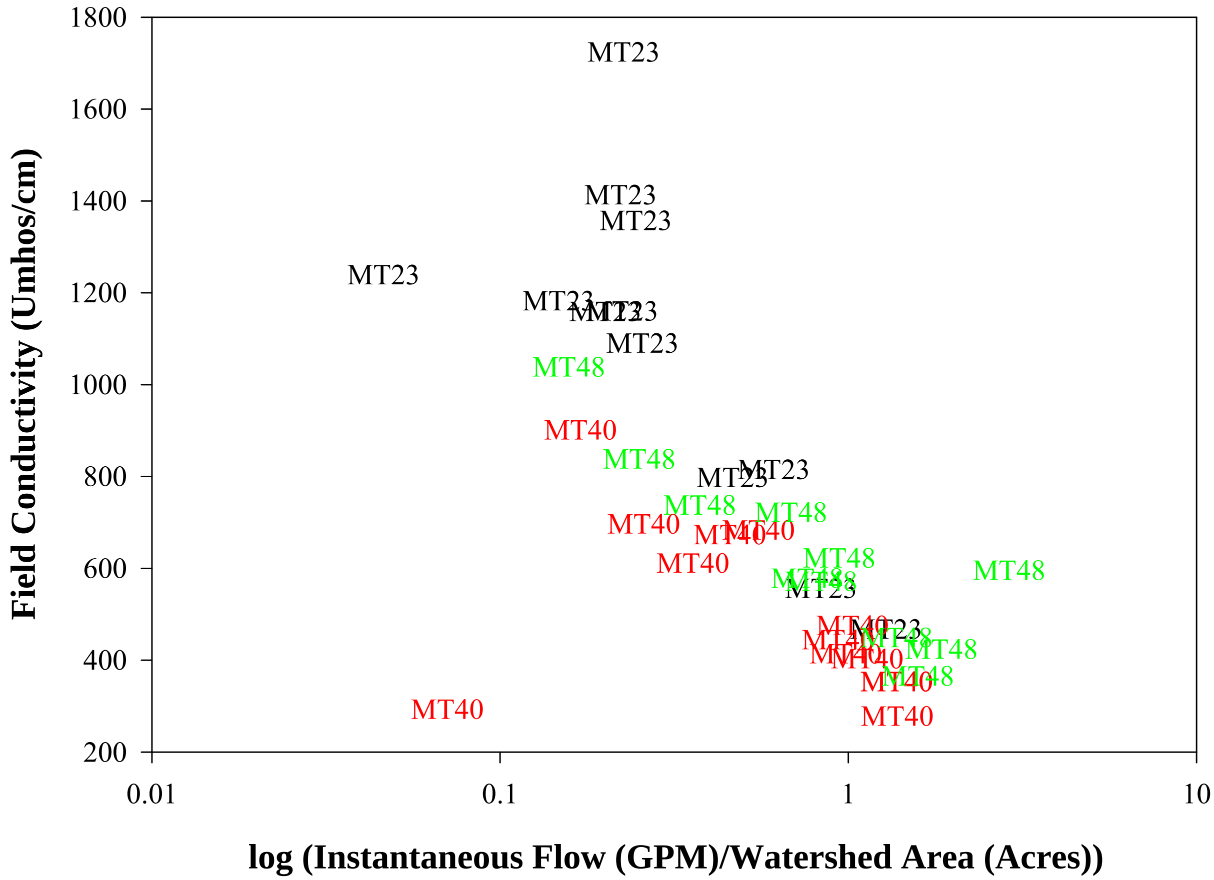
Figure Flow-1. Normalized Flow Rate vs. Date



watershed area) in gallons per minute per acre versus the date. It is noted that the lowest flows are often at Unmined sites. There is a broad range of normalized flow rates for this study area and some variation with the seasons is also evident. There does not appear to be any period of extremely low flow.

Cumulative impacts of MTM/VF mining are difficult to measure but the cumulative impacts on flow rate should be measurable. When the base flows of streams are increased by MTM/VF mining, the base flows of larger streams are also increased. Since the base flows from MTM/VF sites are higher in dissolved minerals, the conductivity of larger streams should increase as low flows occur. Figure Flow-2 plots the conductivity of samples for the three largest watersheds in this study (MT-23 the Mud River near Mud, MT-40 Spruce Fork near Blair, and MT-48 Spruce Fork near Dobra) vs the log of the normalized flow. The pattern of lower flows being associated

Figure Flow-2. Field Conductivity vs. Log (Instantaneous Flow / Watershed Area)



with higher conductivity is evident.

The flow rate data for each sampling event is part of the electronic data base of this report. While outside the scope of this report, there would be value in having experts evaluate the flow rate data comparing it with references and nearby long term stream flow records to identify impacts attributable to mining.

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ATTACHMENT 1

CHEMICAL PARAMETERS IN WEST VIRGINIA WATER QUALITY CRITERIA

Chemical Parameters Selected From West Virginia Water Quality Criteria

The chemical parameter, the water quality limit, and the type of limit are listed in italics. Any comments on the monitoring of each parameter are included in plain type.

Aluminum
Not to exceed 750 ug/L
Acute limits for cold and warm water streams
Total aluminum and dissolved aluminum were monitored in this study.

Ammonia
Limit determined using the tables and formulae in the national Criteria section of USEPA's Ambient Water Quality Criteria for Ammonia 1984 (EPA 440/5-85-001)
Acute and chronic limits for cold and warm water streams
Ammonia is not thought to be a normal contaminant from coal mining activities and was not monitored in this study.

Dissolved Trivalent Arsenic
Not to exceed 360 ug/L (Acute) nor 190 ug/L (Chronic)
Acute and chronic limits for cold and warm water streams.
Arsenic in trivalent form is not thought to be a normal contaminant from coal mining activities. This study monitored for total arsenic concentrations which would include the dissolved trivalent form. This study's grab sample results can be compared to the limit for dissolved trivalent arsenic to indicate the need for expanded monitoring in the future. If the total arsenic values are less than the limit for dissolved trivalent arsenic, no further studies are recommended. If however the total arsenic values are greater than the limit for dissolved trivalent arsenic, then further study might be recommended.

Beryllium
Not to exceed 130 ug/L
Acute limit for cold and warm water streams
Beryllium was monitored during this study.

Dissolved Cadmium
The one-hour average concentration shall not exceed the value determined by the following equation:

$$\text{Cd (ug/L)} = e^{[\{1.128\} \times \{\ln \text{hardness}\} - 3.828]} \times [1.101672 - \{(\ln \text{hardness}) \times (0.041838)\}]$$

Chronic limit for warm and cold water streams (acute limit is higher) -
Only total cadmium concentrations were monitored in the grab samples from the streams. This study's grab sample results can be compared to the one-hour average dissolved cadmium limit to indicate the need for expanded monitoring in the future.

Chloride
Not to exceed 860 mg/L (Acute) nor 230 mg/L (Chronic)
Warm and cold water streams
The 230 mg/L limit was used for this study.

Dissolved Copper
The one-hour average concentration shall not exceed the value determined by the following equation:

$$Cu\ (ug/L) = e^{[0.9422\ \{\ln hardness\}\ -\ 1.464]} \times 0.960$$

Acute limit for warm and cold water streams.
Only total copper concentrations were monitored in the grab samples from the streams. This study's grab sample results can be compared to the one-hour average dissolved copper limit to evaluate the need for expanded monitoring in the future.

Cyanide (as Free Cyanide HCN = CN $^{-)}$
Not to exceed 22ug/L (Acute) nor 5 ug/L(Chronic)
Limits for both warm and cold water streams.
Cyanide is not thought to be a normal contaminant from coal mining activities and was not monitored in this study.

Dissolved Oxygen
Not less than 5 mg/L at any time
Limit for warm water stream.
Field crews monitored for dissolved oxygen during this study.

Dissolved Hexavalent Chromium
Not to exceed 15.3 ug/L(Acute) nor 6.93 ug/L (Chronic)
There are different limits for warm or cold water streams.
Dissolved hexavalent chromium is not thought to be a normal contaminant from coal mining activities. Total chromium was monitored in this study. Total chromium results can be compared to these limits for dissolved hexavalent chromium to evaluate the need for expanded monitoring in the future.

Iron
Not to exceed 1.5 mg/L
Chronic limit for warm and cold water streams.
Total iron was monitored in this study as well as dissolved iron.

Dissolved Lead
The one-hour average concentration shall not exceed the value determined by the following equation:

$$Pb\ (ug/L) = e^{[1.273\{\ln hardness\}\ -\ 1.46]} \times [1.46203 - \{(\ln hardness)(0.145712)\}]$$

Acute limit for warm and cold water streams

Only total lead concentrations were monitored in this study. This study's grab sample results can be compared to the one-hour average dissolved lead limit to evaluate the need for expanded monitoring in the future.

Total Mercury
Not to exceed 2.4 ug/L
Acute limit for warm and cold water streams
Total mercury was monitored in this study.

Methylmercury (water column)
Not to exceed 0.012 ug/L
Chronic limit for warm and cold water streams
Only Total Mercury concentrations were monitored in this study .

Dissolved Nickel
The one-hour average concentration shall not exceed the value determined by the following equation:

$$Ni = e^{[0.846 \{\ln hardness\} + 3.361]} \times [0.997]$$

Chronic limit for both warm and cold water streams
Only total nickel concentrations were monitored in this study. This study's grab sample results can be compared to the one-hour average dissolved nickel limit to evaluate the need for expanded monitoring in the future.

Nitrite (as Nitrite-N)
Not to exceed 1.0 mg/L (warm water stream) nor 0.60 mg/L (cold water stream)
The extremely short holding time for Nitrite analyses forced us to monitor for Nitrate + Nitrite. The Nitrite limit can be compared to the values for Nitrate + Nitrite only for an indication of which sites may possibly have Nitrite contamination.

Organics
Limits for chronic exposure in warm and cold water streams are -

Chlordane - 4.3 ng/L
DDT - 1.0 ng/L
Dieldrin - 1.9 ng/L
Endrin - 2.3 ng/L
Toxaphene - 0.2 ng/L
PCB - 14.0 ng/L
Methoxychlor- 0.03 ug/L

None of these Organics are thought to be a normal contaminant from coal mining activities. They were not included in the list of parameters to be monitored.

pH
No values below 6.0 nor above 9.0 (higher values tolerated if due to photosynthetic activity).

Limits for acute and chronic warm and cold water streams
Field crews monitored for pH during this study.

<u>Phenol</u>
Not to exceed 10,200 ug/L (acute) nor 2,560 ug/L (chronic)
Limits for warm and cold water streams
Phenol is not thought to be a normal contaminant of concern from coal mining activities and was not monitored in this study.

<u>Radioactivity</u>
Gross Beta activity not to exceed 1000 picocuries per liter, etc......
Limits for both warm and cold water streams
Radioactivity is not thought to be a normal contaminant of concern from coal mining activities and was not monitored in this study.

<u>Selenium</u>
Not to exceed 20 ug/L (acute) nor 5 ug/L (chronic)
Limits for warm and cold water streams
The 5 ug/L limit was used for this study.

<u>Silver</u>
The limit varies from 1 ug/L to 43 ug/L depending on the hardness which varies from 0 mg/L to 600 mg/L and whether it is a cold water or warm water stream.
Chronic limits for warm and cold water streams.
Total silver was monitored in this study.

<u>Dissolved Silver</u>
The one-hour average concentration shall not exceed the value determined by the following equation:

$$Ag = e^{[1.72\{\ln \text{hardness}\} - 6.52]} \times 0.85$$

Acute limit for warm and cold water streams -
Only total silver concentrations were monitored in this study.

<u>Temperature</u>
..... not to exceed 87^{O} Fahrenheit during May through November nor 73^{O} Fahrenheit during December through April etc......
Acute limits for warm water streams
Field crews monitored for temperature in this study.

<u>Threshold Odor</u>
Not to exceed a threshold odor number of 8 at 104^{O} Fahrenheit as a daily average

Chronic limit for warm and cold water streams
Threshold Odor is not thought to be a normal contaminant from coal mining and was not monitored in this study.

Total Residual Chlorine
Not to exceed 19 mg/L (acute) nor11 ug/L
Warm water stream limits only - No chlorinated discharge allowed in cold water streams (chronic). Total Residual Chlorine is normally a parameter of concern only at sewage treatment facilities, water treatment plants, chemical plants or swimming pool discharges. It was not monitored in this study.

Turbidity
No discharge shall contribute to a net load of suspended matter such that the turbidity exceeds 10 NTU's over background turbidity when the background is 50 NTU or less, or have more than a 10% increase in turbidity (plus 10 NTU minimum) when the background turbidity is more than 50 NTUs
Chronic limit for warm and cold water streams -
Some of the field meters used in this study had the capability to monitor turbidity. The intermittent readings taken by some of the crews are not included in the results of the study. The limits also require upstream and downstream monitoring which was not part of the study plan.

Dissolved Zinc
The one-hour average concentration shall not exceed the value determined by the following equation:

$$Zn = [e^{\{(0.8743) \times (\ln \text{hardness}) + 0.8604\}}] \times [0.978]$$

Acute limit for warm and cold water streams (chronic limit is higher)-
Only total zinc concentrations were monitored in this study. This study's grab sample results can be compared to the one-hour average dissolved zinc limit to evaluate the need for expanded monitoring in the future.

ATTACHMENT 2

FIELD SHEETS FOR WATER SAMPLING AND FLOW MEASUREMENT

FIELD SHEET - WATER SAMPLING

STATION NUMBER ____________LOCATION____________________________________
DATE mm/dd/yy ____/_____/______TIME (military) ____________________ hours
INVESTIGATOR____
AGENCY ____

FIELD READINGS: Meter Make & ID:
pH __.___ Temperature _____ (C) Dissolved Oxygen (mg/L) ___.___
Conductivity (umhos/cm) _____
Calibration Data: Time:____ Initials:_____
pH Calibration (4.0)_____ (7.0)____ (10.0) ________ (Enter pH readings)
Conductivity Calibration (Conc. of Std. KCl _______), Reading: ________ umhos/cm
DO Calibration (Temp.)_______ (Air Calibration), Reading: _____ [Meters are Auto Altitude]
NIST Thermometer: Reference Temperature (0^0C - Ice/Water in ice chest) Reading: _____
Reference Temperature (Ambient Air Temperature) Reading: ______
Hydrolab Thermometer: Reference Temperature (0^0C - Ice/Water in ice chest) Reading: _____
Reference Temperature (Ambient Air Temperature) Reading: ______

FLOW RATE (Meter Make & ID):
__ gauging sheet attached
__ measured with bucket & stopwatch @ ______(volume) per ____(seconds) = ___liters/sec
__ other method - describe

SAMPLE CONTAINERS FILLED AT THIS SITE (**"*"** Collect Field Duplicate, Mark spaces "**x**" as Collected)
___ ___* 1L (plastic) no chemical preservation for TSS, TDS, Sulfate, Chloride, Acidity, Alkalinity.
____ ____* 250 mL (plastic) preserved with sulfuric acid to pH<2 for Total phosphorous,(NO2+NO3)
____ ____* 40 mL (glass) preserved with sulfuric acid to pH <2 for Total Organic Carbon.
____ ____* 40 mL (glass), filtered, preserved with sulfuric acid to pH <2 for Dissolved Organic Carbon.
____ ____* 500 mL (plastic) preserved with nitric acid to pH <2 for total metals and mercury.
____ ____* 250 mL (plastic), filtered preserved with nitric acid to pH <2 for dissolved metals.
____ No Dup. 250 mL (plastic) preserved with nitric acid to pH <2 for dissolved metals **(Filter Blank, 1/day per crew)**.
____ No Dup. 40 mL (glass) preserved with sulfuric acid to pH <2 for Dissolved Organic Carbon **(Filter Blank, 1/day/crew).**

FIELD FILTRATION

The plastic syringe will be used to suck up a sample from the stream. A new disposable 0.45 micron filter will be screwed on to the syringe and the sample will be filtered into the sample container for shipment to the laboratory. A new syringe and filter will be used at each sample site. The field filtering will comply with the requirements of 40 CFR Part 136, Table IB, note 4. **Filter blanks** will be prepared with lab pure water poured into filtering syringes, dispensed through the filter into the container, and acidified (acid listed above).

Chain of Custody:

Sampler Signature_____________ Date (dd/mm/yy)_____ Time (military)____Hours
Place the above listed samples in the shipping container and seal them for shipment to the lab.

Lab Representative Signature________________. Received the above listed samples into the Laboratory custody on Date (mm/dd/yy) ________Time (military) _____ Hours.

FIELD SHEET - FLOW MEASUREMENT

STATION NUMBER ____________LOCATION_____________________________________
DATE mm/dd/yy ____/_____/______TIME (military) ____________________ hours
INVESTIGATOR(S)____
AGENCY ____

Distance From Bank	Depth of Water	Depth of Reading	Velocity

OBSERVATIONS: (over if required)

ATTACHMENT 3

INFORMATION ON PARAMETERS MONITORED

Information on Parameters Monitored				
Parameter	**Method ***	**"Frequency of Collection**	**Sample Preservation/Holding Time (ice to < 4C,acid to pH<2)**	**Method Detection Limits** (ug/l)**
Flow Rate	USGS stream gaging protocol modified to use electromagnetic velocity meter	On each sampling occasion at all 37 sites	not applicable	not applicable
Temperature (°C),	***EPA 170.1*** **{*Hydrolab*** type multiparameter field meter, *in situ*. See Section D.**]**	On each sampling occasion at all 37 sites	not applicable, *in situ*	not applicable
Dissolved Oxygen*** (mg/l),	***EPA 170.1*** **[*Hydrolab*** type multiparameter field meter, *in situ****.* See Section D.]*** EPA 360.1 [in situ]	On each sampling occasion at all 37 sites	not applicable, *in situ*	not applicable (Capable of ± 0.2 mg/L*)
pH*** (su),	***[Hydrolab*** type multiparameter field meter, *in situ****.* See Section D.***] EPA 150.1 [in situ]	On each sampling occasion at all 37 sites	not applicable, *in situ*	not applicable (Capable of measuring +/- 0.2 SU*)
Conductivity (umhos/cm)	***[Hydrolab*** type multiparameter field meter, *in situ****.* See Section D.]*** EPA 120.1 [in situ]	On each sampling occasion at all 37 sites	not applicable, *in situ*	not applicable
Total Suspended Solids	EPA 160.2	Monthly	Ice/7 days	5000
Total Dissolved Solids	EPA 160.1	Monthly	Ice/7 days	5000
Acidity	EPA 305.1	Monthly	Ice/14 days	2000
Alkalinity	EPA 310.1	Monthly	Ice/14 days	4000
Sulfate	EPA 375.4	Monthly	Ice/28 days	10000
Nitrate+Nitrite	EPA 300.0 Unless acid preservative interferes	Monthly	Ice/H_2SO_4/28 Days	100
Total Phosphorous	EPA 365.4	Monthly	Ice/H_2SO_4 /28 Days	10
Total Organic Carbon	EPA 415.1	Monthly	Ice/H_2SO_4 /28 Days	1000
Dissolved Organic Carbon	EPA 415.1	Monthly	Field filtered **(see Appendix A)** Ice/H_2SO_4 /28 Days	1000

Information on Parameters Monitored				
Parameter	**Method ***	**"Frequency of Collection**	**Sample Preservation/Holding Time (ice to < 4C,acid to pH<2)**	**Method Detection Limits** (ug/l)**
Dissolved Metals Al, Fe, Mn	EPA 200.7	Monthly	Field filtered **(see Appendix A)** Ice/HNO_3 /6 months	100
Chloride***	EPA 300.0	Monthly	Ice/28 days	80000
Total K, Na	EPA 258.1, 273.1	Monthly	Ice/HNO_3 /6 months	1000
Total Al***,	EPA 200.7	Monthly	Ice/HNO_3 /6 months	250
Ca, Mg, Mn	EPA 200.7	Monthly	Ice/HNO_3 /6 months	100
Hardness	EPA 200.7 (Calculated from Ca + Mg) 2340B APHA	Monthly	Ice/HNO_3 /6 months	Not Applicable
Total, Cr, Zn	EPA 200.7	Monthly	Ice/HNO_3 /6 months	10
Total Ag	EPA 200.7	Monthly	Ice/HNO_3 /6 months	10
Total Cu	EPA 200.7	Monthly	Ice/HNO_3 /6 months	10
Total Fe***	EPA 200.7	Monthly	Ice/HNO_3 /6 months	500
Total Ni	EPA 200.7	Monthly	Ice/HNO_3 /6 months	10
Total Be***	EPA 200.7	Monthly	Ice/HNO_3 /6 months	40
Total As	EPA 200.7	Monthly	Ice/HNO_3 /6 months	5
Total Cd	EPA 200.7	Monthly	Ice/HNO_3 /6 months	5
Total Pb	EPA 200.7	Monthly	Ice/HNO_3 /6 months	5
Total Se***	EPA 200.7	Monthly	Ice/HNO_3 /6 months	2
Total Sb	EPA 200.7	Monthly	Ice/HNO_3 /6 months	5
Total Tl	EPA 200.7	Monthly	Ice/HNO_3 /6 months	5
Total Hg***	EPA 245.1	Monthly	Ice/HNO_3 /6 months	0.8

***Other equivalent 40CFR Part 136 Methods may be substituted in order to meet the needed Method Detection Limits listed.**

****The method detection limits listed are not critical if ambient levels are routinely measured at significantly higher levels. If the detection levels listed for WVWQSC analytes can not be achieved and the routine ambient levels are not detectable, the Project Officer must be notified.**

***** Denotes parameter with applicable West Virginia Water Quality Stream Criteria (WVWQSC) for aquatic life**.

ATTACHMENT 4

ELECTRONIC SPREADSHEET OF THE RESULTS OF THE STUDY

Ecological Assessment of Streams in the Coal Mining Region of West Virginia Using Data Collected by the U.S. EPA and Environmental Consulting Firms

Interim Results
April 11, 2002

Assessment Objectives

Currently, there are three major reports generated from the U.S. EPA Region 3's collection of ecological data in the MTM/VF Region of West Virginia (i.e., Green et al., 2000 Draft; U.S. EPA Region 3, 2001 Draft; and Stauffer and Ferreri, 2000); separate reports for macroinvertebrates, fish, and water chemistry data, respectively. The primary analysis in these reports is descriptive in nature. In addition, mining companies have collected an extensive amount of biomonitoring data that could also be incorporated in the EIS analysis. An integrated analysis of maining company and Region 3 data would increase the sample size for the EIS and potentially provide more information regarding the relationships among water chemistry, fish, macroinvertebrates and EIS classes. There are two primary objectives of the integrated assessment. The first of these objectives is to perform an analysis of the data collected by Region 3 and the data collected by mining company consultants, BMI, REIC and POTESTA. Results will be presented in a single report. The analysis will include two components: 1) a statistical evaluation of the EIS classes for fish and for macroinvertebrates, and 2) a statistical evaluation of the potential additive effects along the main stems of two watersheds for fish and macroinvertebrates. A second objective is an examination of chemical and physical habitat factors that may contribute to any potential differences among EIS classes detected for fish and invertebrates. Insights gained from the second objective may provide information to develop guidance to "minimize, to the maximum extent practicable, the adverse environmental effects to the waters of the United States and to fish and wildlife resources from mountaintop mining operations, and to environmental resources that could be affected by the size and location of fill material in valley fill sites".

Assessment Watersheds and Sites

Sites from six watersheds are included in the assessment: Mud River, Spruce Fork, Clear Fork, Twentymile Creek, Island Creek, and Twelvepole Creek. Each of these watersheds are within the MTM/VF Region of West Virginia. Two of the watersheds, Island Creek and Twentymile Creek, have both Region 3 and mining company sites where data were collected. One watershed, Twelvepole Creek, has only mining company data and three watersheds, Mud River, Spruce Fork and Clear Fork, have only Region 3 data. Tables 1 to 6 show the distribution of sites across EIS classes in each of the watersheds and the entity that provided the data. These sites represent a combination of water chemistry, habitat, fish and macroinvertebrate data. Some sites have a full set of indicator data collected (fish, macroinvertebrates, water chemistry, and habitat), whereas other sites only have a subset of indicator data. The least amount of data available is for habitat. Sampling occurred seasonally beginning in Spring of 1999 and ending in Winter 2001. Not all sites were sampled in each season. Only two watersheds provide sufficient data for the additive analysis, Twentymile Creek and Twelvepole Creek.

Table 1. Sites sampled in the Mud River Watershed.

Site ID/Organization	Stream Name	EIS Class
U.S. EPA Region 3		
MT01	Mud River	Mined/Residential
MT02	Rushpatch Branch	Unmined
MT03	Lukey Fork	Unmined
MT13	Spring Branch	Unmined
MT14	Ballard Fork	Filled
MT15	Stanley Fork	Filled
MT24	Unnamed Trib. to Stanley Fork	Sediment Control Structure
MT18	Sugartree Branch	Filled
MT23	Mud River	Filled/Residential
MT106	Unnamed Trib. to Sugartree Branch	Mined

Table 2. Sites sampled in the Spruce Fork Watershed.

Site ID/Organization	Stream Name	EIS Class
U.S. EPA Region 3		
MT39	White Oak Branch	Unmined
MT40	Spruce Fork	Filled/Residential
MT42	Oldhouse Branch	Unmined
MT45	Pigeonroost Branch	Mined
MT32	Beech Creek	Filled
MT34B	Left Fork	Filled
MT48	Spruce Fork	Filled/Residential
MT25B	Rockhouse Creek	Filled

Table 3. Sites sampled in the Clear Fork Watershed.

Site ID/Organization	Stream Name	EIS Class
U.S. EPA Region 3		
MT79	Davis Fork	Mined
MT78	Raines Fork	Mined
MT81	Sycamore Creek	Mined
MT75	Toney Fork	Filled/Residential
MT70	Toney Fork	Filled/Residential
MT69	Ewing Fork	Mined/Residential
MT64	Buffalo Fork	Filled
MT62	Toney Fork	Filled/Residential

Table 4. Sites sampled in the Twentymile Creek Watershed. Equivalent sites are noted parenthetically.

Site ID/Organization	Stream Name	EIS Class
U.S. EPA Region 3		
MT95 (=Neil-5)	Neil Branch	Unmined
MT91	Rader Fork	Unmined
MT87 (=Rader-4)	Neff Fork	Filled
MT86 (=Rader-7)	Rader Fork	Filled
MT103	Hughes Fork	Filled
MT98	Hughes Fork	Filled
MT104	Hughes Fork	Filled
BMI Sites		
Rader 8	Twentymile Creek	Additive
Rader 9	Twentymile Creek	Additive
PMC-TMC-36	Twentymile Creek	Additive
PMC-TMC-35	Twentymile Creek	Additive
PMC-TMC-34	Twentymile Creek	Additive
PMC-TMC-33	Twentymile Creek	Additive
PMC-TMC-31	Twentymile Creek	Additive
PMC-TMC-30	Twentymile Creek	Additive
PMC-TMC-29	Twentymile Creek	Additive
PMC-TMC-28	Twentymile Creek	Additive
PMC-TMC-27	Twentymile Creek	Additive
PMC-TMC-26	Twentymile Creek	Additive
PMC-7	Twentymile Creek	Additive
PMC-6	Twentymile Creek	Additive
PMC-5	Twentymile Creek	Additive
PMC-TMC-4	Twentymile Creek	Additive
PMC-TMC-5	Twentymile Creek	Additive
PMC-TMC-314	Twentymile Creek	Additive
PMC-TMC-2	Twentymile Creek	Additive
PMC-TMC-1	Twentymile Creek	Additive

Continued

Table 4 (Continued).

Site ID/Organization	Stream Name	EIS Class
BMI Sites		
PMC-HWB-1	Twentymile Creek	Additive
PMC-HWB-2	Twentymile Creek	Additive
Neil-6 (=Fola 48)	Twentymile Creek	Additive
Neil-7 (=Fola 49)	Twentymile Creek	Additive
Neil-2 (=Fola 53)	Neil Branch	Unmined
Neil-5 (=MT95)	Neil Branch	Unmined
Rader-1	Laurel Run	Unmined
Rader-2	Rader Fork	Unmined
Rader-3	Trib. to Rader	Unmined
Rader-4 (=MT87)	Neff Fork	Filled (2)
Rader-5	Neff Fork	Filled (2)
Rader-6	Trib. to Neff	Filled (1)
Rader-7 (=MT86)	Rader Fork	Filled (2)
PMC-1	Sugarcamp Branch	Filled (1)
PMC-11	Right Fork	Filled (1)
PMC-12	Road Fork	Filled (1)
PMC-15	Tributary to Robinson Fork.	Filled (1)
POTESTA Sites		
Fola 33	Twentymile Creek	Additive
Fola 36	Twentymile Creek	Additive
Fola 37	Twentymile Creek	Additive
Fola 38	Twentymile Creek	Additive
Fola 48 (=Neil-6)	Twentymile Creek	Additive
Fola 49 (=Neil-7)	Twentymile Creek	Additive
Fola 39	Peachorchard Branch	Filled (2 small)
Fola 40	Peachorchard Branch	Filled (1 small)
Fola 45	Peachorchard Branch	Unmined
Fola 53 (=Neil-2)	Neil Branch	Unmined

Table 5. Sites sampled in the Island Creek Watershed.

Site	Stream Name	EIS Class
U.S. EPA Region 3		
MT50	Cabin Branch	Unmined
MT51	Cabin Branch	Unmined
MT107	Left Fork	Unmined
MT52	Cow Creek	Filled
MT57B	Hall Fork	Filled
MT57	Hall Fork	Filled
MT60	Left Fork	Filled
MT55	Cow Creek	Filled/Residential
BMI Sites		
Mingo 34		Filled (1)
Mingo 41		Filled (2)
Mingo 39		Filled (1) + old mining
Mingo 16		Unmined
Mingo 11		Unmined
Mingo 2		Unmined
Mingo 86		Unmined
Mingo 62		Unmined
Mingo 38	Island Creek	Additive
Mingo 24	Island Creek	Additive
Mingo 23	Island Creek	Additive

Table 6. Sites sampled in the Twelvepole Creek Watershed. Equivalent sites are noted parenthetically.

Site ID/Organization	Stream Name	EIS Class
REIC Sites		
BM-001A	Twelvepole Creek	Additive
BM-001C	Twelvepole Creek	Additive
BM-001B	Twelvepole Creek	Additive
BM-001	Twelvepole Creek	Additive
BM-010	Twelvepole Creek	Additive
BM-011	Twelvepole Creek	Additive
BM-002	Twelvepole Creek	Additive
BM-002A	Twelvepole Creek	Additive
BM-003A	Kiah Creek	Additive
BM-003	Kiah Creek	Additive
BM-004	Kiah Creek	Additive
BM-004A	Kiah Creek	Additive
BM-005	Trough Fork	Additive
BM-006	Trough Fork	Additive
BM-UMC	Milam Creek	Unmined
BM-DMC	Milam Creek	Unmined
BM-DBLC	Laurel Creek	Unmined
BM-UBLC	Laurel Creek	Unmined

Analyses Planned

Multiple statistical evaluations are planned for the data. The primary analyses are:

1. Are there any differences among EIS classes for fish and for macroinvertebrates? EIS classes included in this evaluation are Unmined, Mined, Filled and Filled with Residences. The variables for these analyses are the West Virginia Stream Condition Index (SCI) for macroinvertebrates and a set of eight macroinvertebrate metrics included in the Region 3 report and the mid-Atlantic Index of Biotic Integrity (IBI) for fish and the nine component metrics for the IBI.

2. For the mainstem of Twentymile Creek, Twelvepole Creek and Kiah Creek: Is there a trend in the biological condition relative to the distance along the mainstem? The distance variable is a surrogate measure for additive mining and valley fill impacts. The response variables are the same analysis variables as number one above.

3. An examination of chemical and physical habitat factors that may contribute to any potential differences among EIS classes detected for fish and invertebrates. Chemical and physical habitat variables will be paired with fish and invertebrate metrics to look for significant correlations. Similar analyses will be conducted along the mainstem of Twentymile Creek, Twelvepole Creek and Kiah Creek.

Analyses Completed

EPA Region III Macroinvertebrate Data Results

Results of One-way Analysis of Variance (ANOVA) for the SCI and eight macroinvertebrate metrics are given in Tables 7 to 11. Sites were not consistently sampled across seasons due to drought conditions in the Summer and Fall of 1999. For this reason, analyses were done separately for each season. Least squares means with a Dunnett's adjustment was used to test for differences in EIS classes relative to a reference or unmined condition. Results are consistent across seasons. For the SCI and each metric across all seasons, except HBI in the Fall of 1999, significant differences among EIS classes were detected. In addition, multiple comparisons results indicated significant differences between unmined or reference condition and the filled sites, filled with residences or both for every metric, SCI and season combination (except HBI in the Fall of 1999).

Preliminary results of the analysis of the combined Region III and mining company data, support these conclusions.

Table 7: Region 3 Macroinvertebrate Data Results for Spring 1999

Total Number of Observations = 41
EIS Classes: Unmined, WV – MTM Reference, Mined, Filled, Filled & Residences
LS Means Comparisons: Unmined as comparative control

Response	ANOVA F-test p-value	Normality	Equal Variance	LS Means Results
SCI	<0.0001	Yes	Yes	F,F&R
Total Taxa	0.0199	Yes	Yes	F,F&R
EPT Taxa	0.0004	Yes	Yes	F,F&R
% EPT	<0.0001	Yes	Yes	F&R
HBI	<0.0001	Yes	Yes	F&R
% 2 Dominant	<0.0001	Yes	Yes	F,F&R
Mayfly Taxa	0.0003	Yes	Yes	F,F&R
% Mayflies	<0.0001	Yes	Yes	F,F&R
% Chironomidae	0.0003	Yes	Yes	F&R

Table 8: Region 3 Macroinvertebrate Data Results for Summer 1999

Total Number of Observations = 28
EIS Classes: WV – MTM Reference, Filled, Filled & Residences
LS Means Comparisons: WV – MTM Reference as comparative control

Response	ANOVA F-test p-value	Normality	Equal Variance	LS Means Results
SCI	<0.0001	Yes	Yes	F,F&R
Total Taxa	0.0016	Yes	Yes	F,F&R
EPT Taxa	<0.0001	Yes	Yes	F,F&R
% EPT	<0.0001	Yes	Yes	F,F&R
HBI	<0.0001	Yes	Yes	F,F&R
% 2 Dominant	0.0063	Yes	Yes	F,F&R
Mayfly Taxa	<0.0001	Yes	Yes	F,F&R
% Mayflies	<0.0001	Yes	No	F,F&R
% Chironomidae	0.0083	Yes	Yes	F&R

Table 9: Region 3 Macroinvertebrate Data Results for Fall 1999

Total Number of Observations = 27
EIS Classes: WV – MTM Reference, Filled, Filled & Residences
LS Means Comparisons: WV – MTM Reference as comparative control

Response	ANOVA F-test p-value	Normality	Equal Variance	LS Means Results
SCI	<0.0001	Yes	Yes	F,F&R
Total Taxa	0.0110	Yes	Yes	F
EPT Taxa	<0.0001	Yes	Yes	F,F&R
% EPT	0.0036	Yes	Yes	F&R
HBI	0.0257	Yes	Yes	None
% 2 Dominant	0.0204	Yes	Yes	F
Mayfly Taxa	<0.0001	Yes	Yes	F,F&R
% Mayflies	<0.0001	Yes	No	F,F&R
% Chironomidae	0.0123	Yes	Yes	F&R

Table 10: Region 3 Macroinvertebrate Data Results for Spring 2000

Total Number of Observations = 43
EIS Classes: Unmined, WV - MTM Reference, Mined, Filled, Filled & Residences
LS Means Comparisons: Unmined as comparative control

Response	ANOVA F-test p-value	Normality	Equal Variance	LS Means Results
SCI	<0.0001	Yes	No	F,F&R
Total Taxa	0.0040	No	Yes	F
EPT Taxa	0.0003	Yes	Yes	F,F&R
% EPT	<0.0001	Yes	No	F,F&R
HBI	<0.0001	Yes	No	F,F&R
% 2 Dominant	0.0002	Yes	Yes	F,F&R
Mayfly Taxa	<0.0001	Yes	Yes	F,F&R
% Mayflies	0.0003	Yes	Yes	F,F&R
% Chironomidae	<0.0001	Yes	Yes	F&R

Table 11: Region 3 Macroinvertebrate Data Results for Winter 2000

Total Number of Observations = 39
EIS Classes: Unmined, WV – MTM Reference, Mined, Filled, Filled & Residences
LS Means Comparisons: Unmined as comparative control

Response	ANOVA F-test p-value	Normality	Equal Variance	LS Means Results
SCI	<0.0001	Yes	Yes	F,F&R
Total Taxa	0.0131	Yes	Yes	F&R
EPT Taxa	0.0010	Yes	Yes	F&R
% EPT	<0.0001	Yes	Yes	F,F&R
HBI	<0.0001	Yes	Yes	F,F&R
% 2 Dominant	0.0002	Yes	Yes	F&R
Mayfly Taxa	<0.0001	Yes	No[#]	F,F&R
% Mayflies	<0.0001	Yes	Yes	F,F&R
% Chironomidae	<0.0001	Yes	Yes	F,F&R

The variability of the three mined sites is zero.

Combined Region 3/Penn State and Mining Company Fish Data

The combined fish data for Region 3/Penn State and mining companies were analyzed for differences among EIS classes. There was inconsistency in the number of seasons that sites were sampled and several sites were sampled in only one season. This limited the ability to complete a seasonal analysis for the fish data. For this reason, the IBI and component metric values for all sites sampled multiple times were averaged across season, and the mean value for a site was used in all subsequent analysis. The distributions of IBI scores in each of the EIS classes are shown in Figure 1. Distributions of the nine component metrics for the IBI are shown in Figures 2 to10. For comparison, the regional reference sites sampled by Penn State University (PSU) in Big Ugly Creek are also included in the plots. The data in Figure 1 indicates that the Filled and Mined classes have lower IBI scores overall than all other EIS classes. The Filled with Residences class had higher IBI scores than the Filled and the Mined classes. The Filled with Residences class and the Unimined class had similar median scores to the regional reference sites, although all EIS classes showed greater variability in IBI scores than the regional reference. Figure 1 shows that more than half of the Filled and Mined EIS classes scored “poor” according to the ratings developed by McCormick et al. (2001). Unmined and regional reference sites were primarily in the “fair” range.

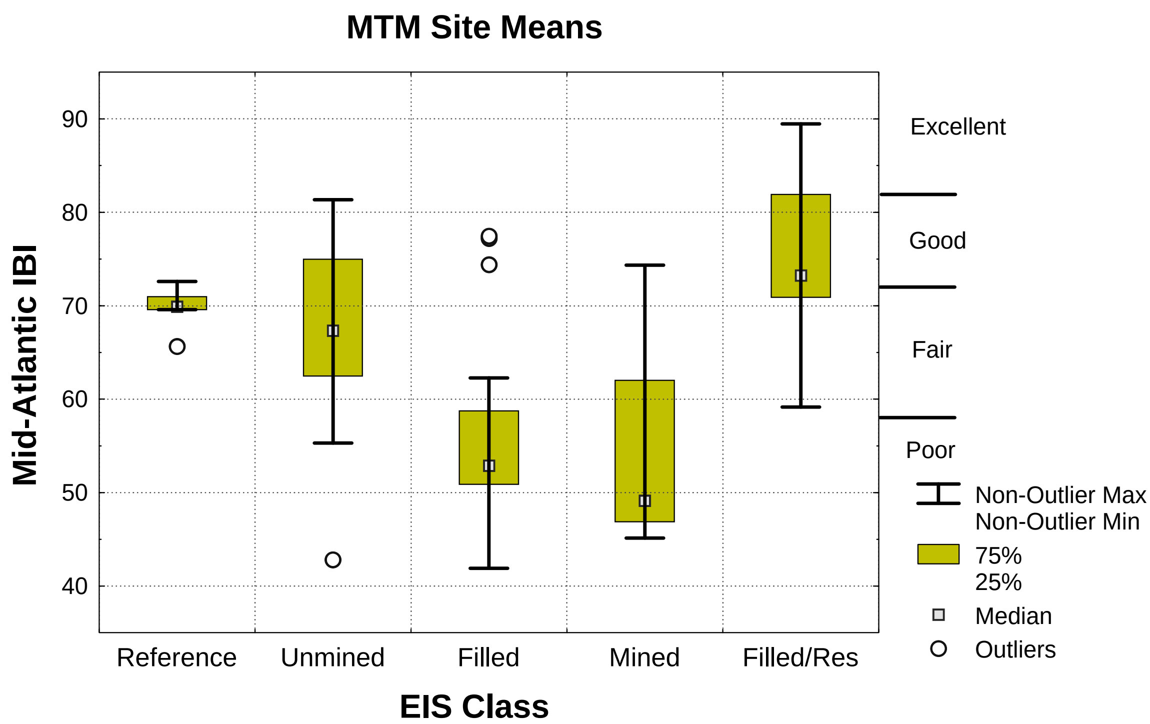


Figure 1. Box and whisker plot of mean IBI scores of sampling sites in 5 classes. Catchments less than 2 km^2 and samples less than 10 fish excluded. "Reference" are 5 regional reference sites in Big Ugly Creek, outside of study area. All other sites in MTM study watersheds. Assessment categories (McCormick et al.2001) shown on right side.

IBI scores were plotted , and did not deviate from expectations of normality. Because IBI scores were normally distributed, we used standard analysis of variance (ANOVA) to test differences among EIS classes, and Dunnett's test to compare each class to the Unmined (Control) class. Differences among the EIS classes were statistically significant (Table 12) by ANOVA, and the Dunnett's one-tailed test showed that the Filled IBI scores were significantly lower than the Unmined IBI scores (Table 13). Neither the Mined nor the Filled with Residences classes had significantly lower IBI scores than the Unmined class; in fact, the Filled with Residences class had higher IBI scores than the Unmined class (see Fig.1).

Table 12. Analysis of variance of IBI scores among EIS classes (Unmined, Filled, Mined, and Filled/Residential)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2335.56	778.52	6.70	0.0009
Error	40	4651.31	116.28		
Corrected Total	43	6986.87			

R-Square	Coeff Var	Root MSE	INDEX Mean
0.334	17.022	10.783	63.35

Table 13. Dunnett's test comparing IBI values of EIS classes to the Unmined class. Comparisons significant at 0.05 are indicated by ***

Alpha	0.05
Error Degrees of Freedom	40
Error Mean Square	116.28
Critical Value of Dunnett's t	2.15

EIS_CLAS Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Filled/R - Unmined	7.919	-Infinity	17.833	
Filled - Unmined	-9.860	-Infinity	-1.485	***
Mined - Unmined	-12.227	-Infinity	0.930	

The individual metrics that comprise the IBI are not uniform in their response to stressors (McCormick et al. 2001): some may respond to habitat degradation, some may respond to organic pollution, and some may respond to toxic chemical contamination. Of the nine metrics in the IBI, two were statistically significantly different among the EIS classes: the number of minnow species and the number of benthic invertivore species (Figures 2 and 4). On average, Filled sites were missing one species of each of these two groups compared to Unmined sites. The third taxa richness metric, Number of Intolerant Species, was not different between Filled and Unmined sites (Figure 7). Two additional metrics, Percent Predators and Percent Tolerant Individuals, showed increased degradation in Filled sites compared to Unmined sites, on average, but the difference was not statistically significant (Figures 6 and 10). Four metrics in the data set were dominated by zero values: Percent Sculpins, Percent Gravel Spawners, Percent Non-native Fish, and Percent Large Omnivores (Figures 3, 5, 8 and 9). Because of the zero values and the resultant non-normal distribution, parametric hypothesis tests (e.g., ANOVA) are problematic.

Figure 2: Number of Invertivore Species

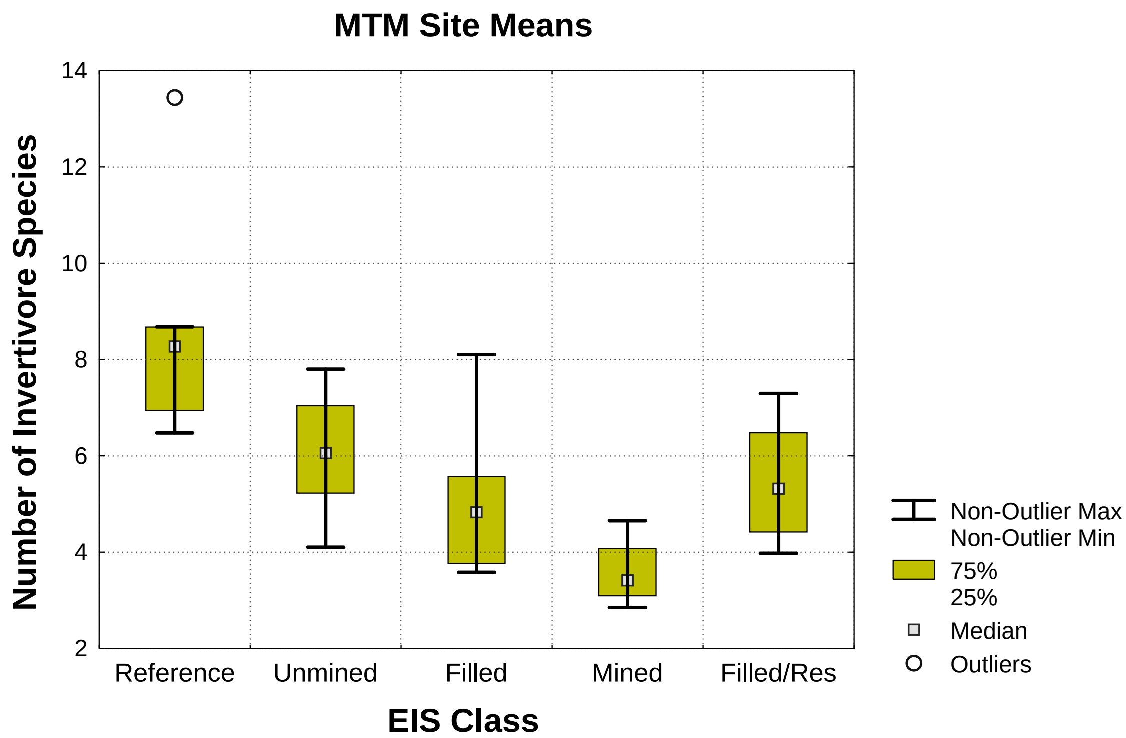


Figure 3: Percent Sculpins

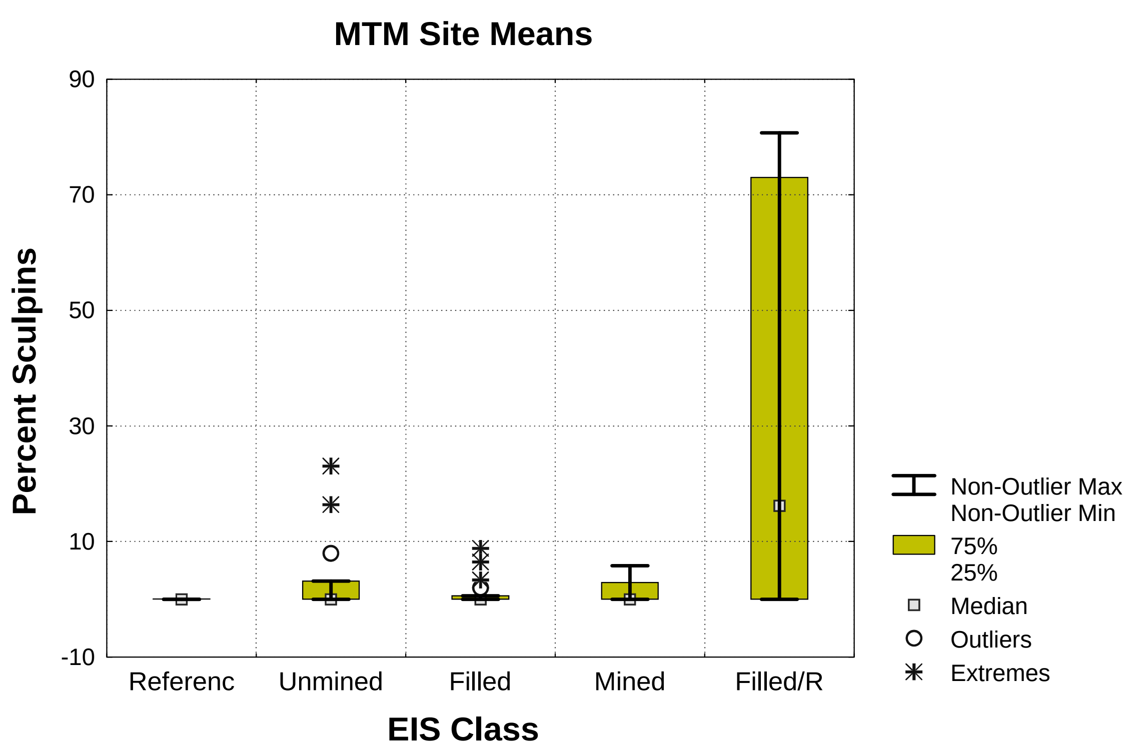


Figure 4: Number of Minnow Species

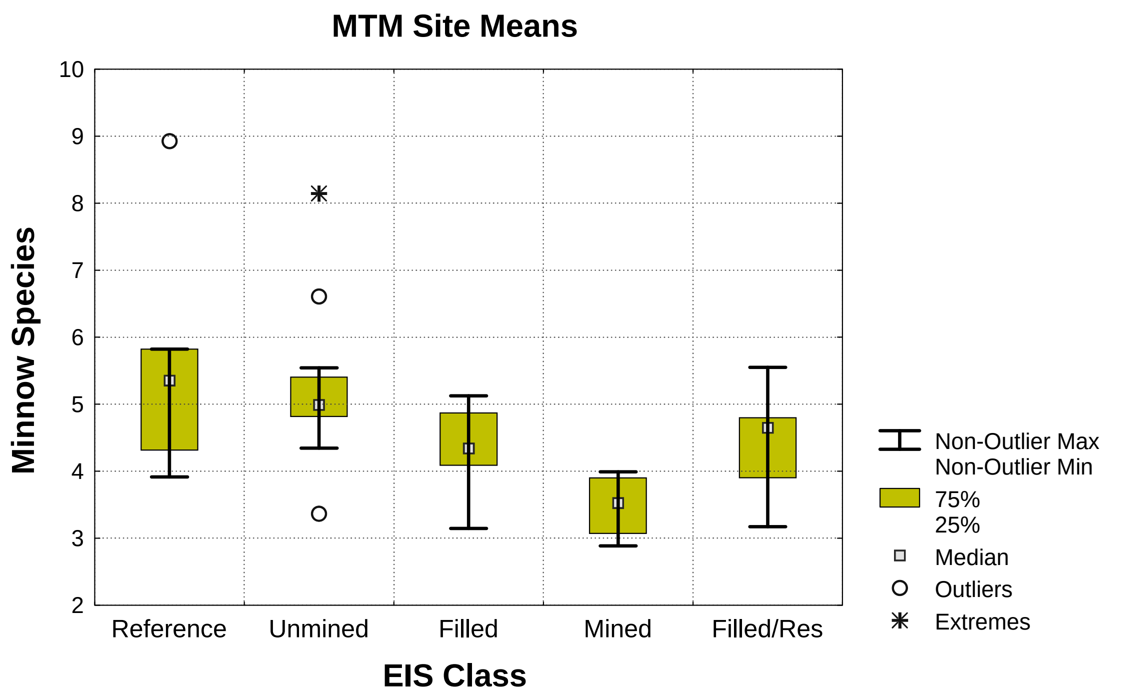


Figure 5: Percent of individuals that are gravel spawners

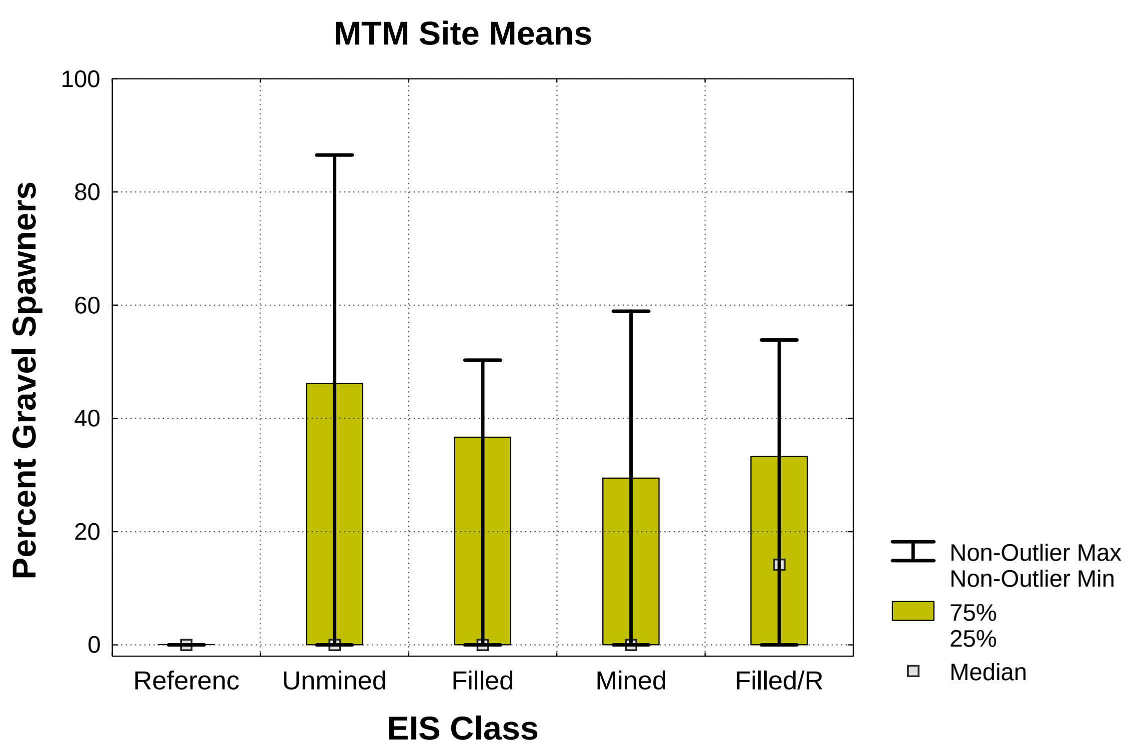


Figure 6: Percent Predators

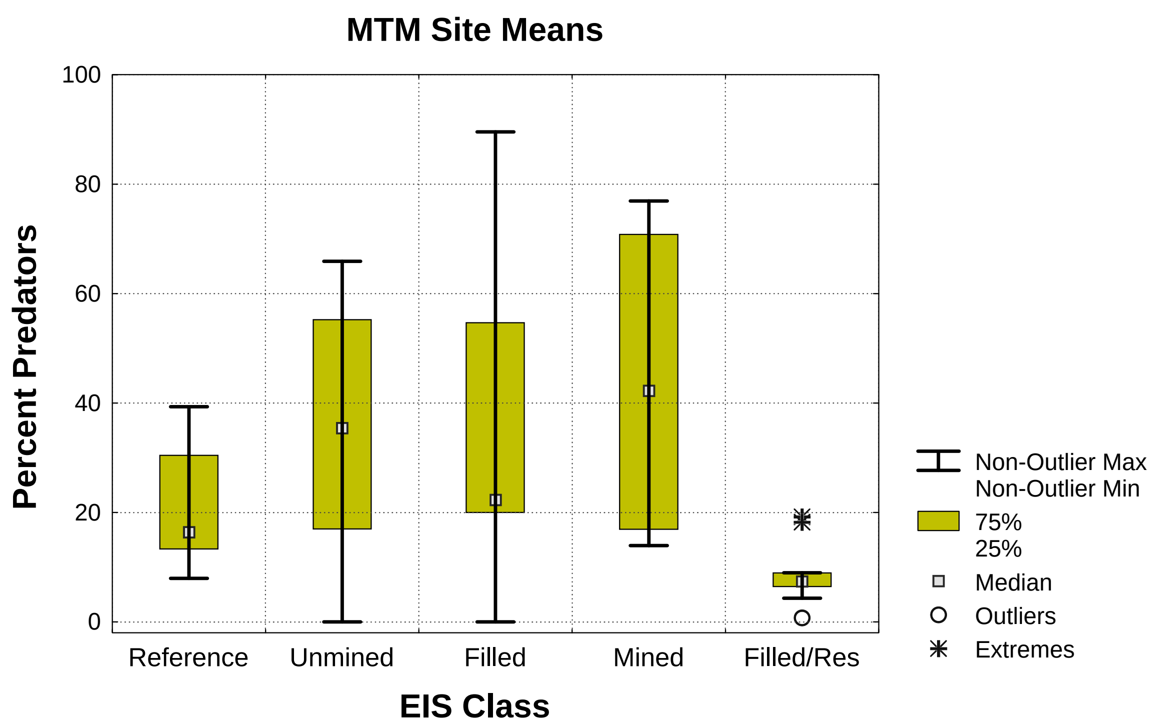


Figure 7: Number of Intolerant Species

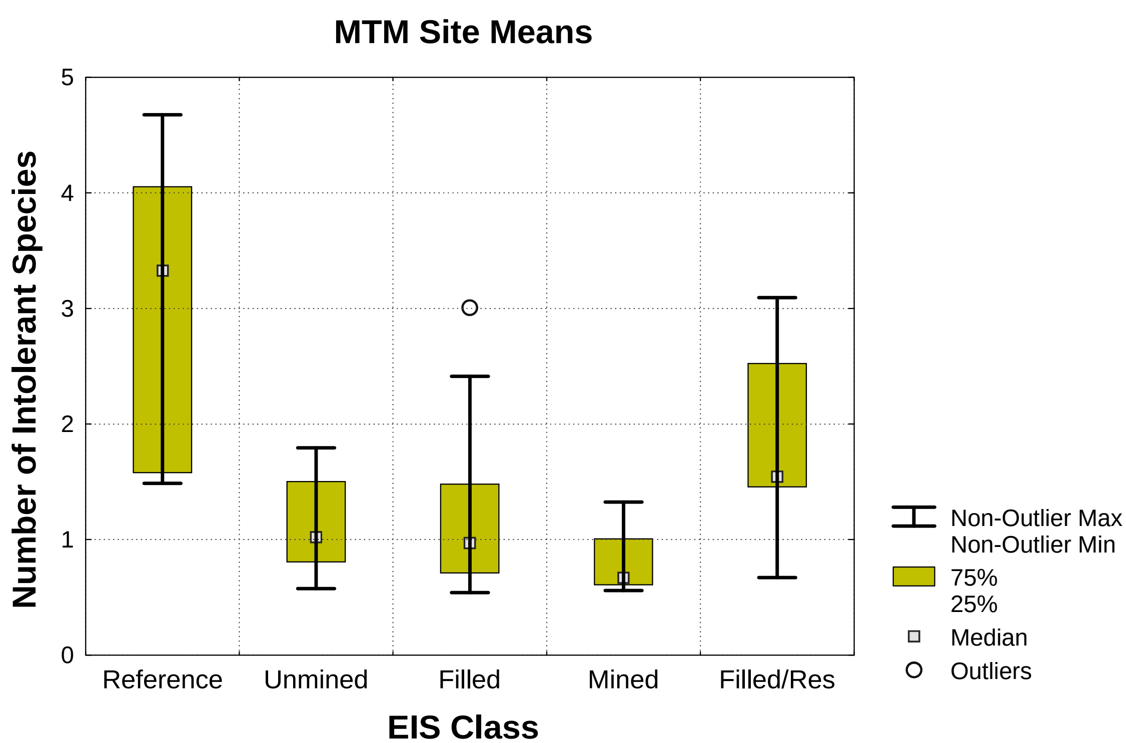


Figure 8: Percent of Fish that are not native

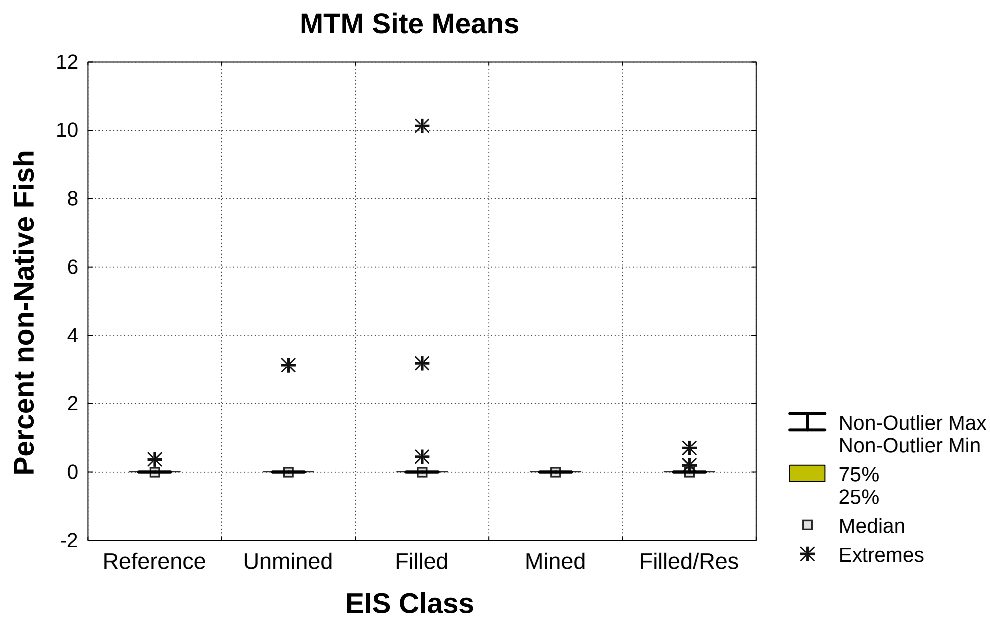


Figure 9: Percent of individuals that are large omnivores

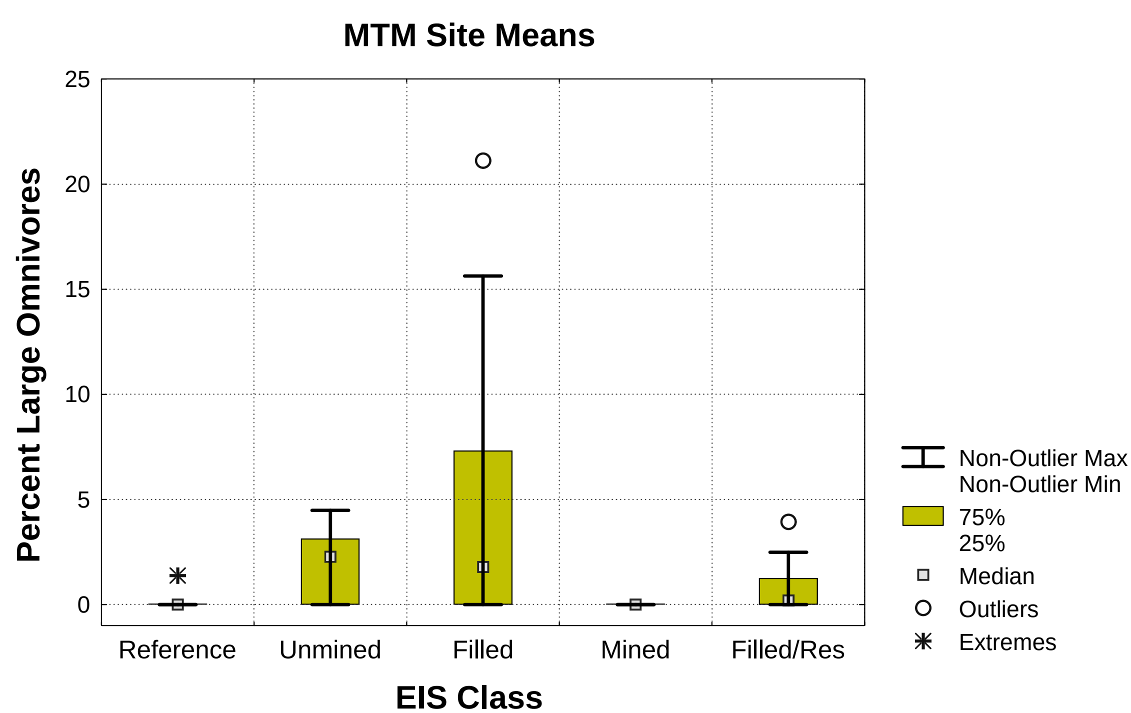
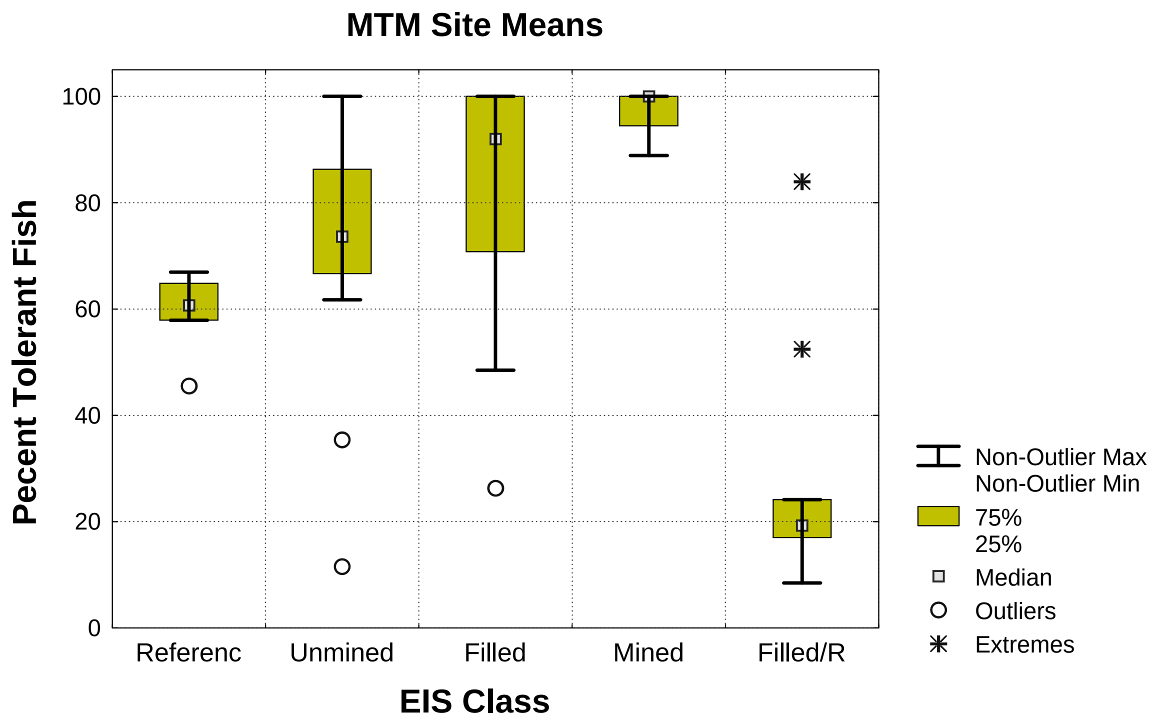


Figure 10: Percent of individuals that are tolerant



Ecological Assessment of Streams in the Coal Mining Region of West Virginia Using Data Collected by the U.S. EPA and Environmental Consulting Firms

February 2003

Prepared by:

Florence Fulk and Bradley Autrey
U.S. Environmental Protection Agency
National Exposure Research Laboratory
Cincinnati, Ohio

John Hutchens
Coastal Carolina University
Conway, South Carolina

Jeroen Gerritsen, June Burton, Catherine Cresswell, and Ben Jessup
Tetra Tech, Inc.
Owings Mills, Maryland

U.S. Environmental Protection Agency
National Exposure Research Laboratory
26 W. Martin Luther King Drive
Cincinnati, Oh 45268

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EXECUTIVE SUMMARY

INTRODUCTION

Recently, the Mountaintop Mining (MTM) and Valley Fill (VF) operations in the Appalachian Coal Region have increased. In these operations, the tops of mountains are removed, coal materials are mined and the excess materials are deposited into adjacent valleys and stream corridors. The increased number of MTM/VF operations in this region has made it necessary for regulatory agencies to examine the relevant regulations, policies, procedures and guidance needed to ensure that the potential individual and cumulative impacts are considered. This necessity has resulted in the preparation of an Environmental Impact Statement (EIS) concerning the MTM/VF activities in West Virginia. The U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers, U.S. Office of Surface Mining, and U.S. Fish and Wildlife Service, in cooperation with the West Virginia Department of Environmental Protection, are working to prepare the EIS. The purpose of the EIS is to establish an information foundation for the development of policies, guidance and coordinated agency decision-making processes to minimize, to the greatest practicable extent, the adverse environmental effects to the waters, fish and wildlife resources in the U.S. from MTM operations, and to other environmental resources that could be affected by the size and location of fill material in VF sites. Furthermore, the EIS's purpose is to determine the proposed action, and develop and evaluate a range of reasonable alternatives to the proposed action.

The U.S. EPA's Region 3 initiated an aquatic impacts study to support the EIS. From the spring 1999 through the winter 2000, U.S. EPA Region 3 personnel facilitated collection of water chemistry, habitat, macroinvertebrate and fish data from streams within the MTM/VF Region. In addition, data were also collected by three environmental consulting firms, representing four coal mining companies. The National Exposure Research Laboratory (NERL) of the U.S. EPA's Office of Research and Development assembled a database of U.S. EPA and environmental consulting firm data collected from the MTM/VF Region. Using this combined data set, NERL analyzed fish and macroinvertebrate data independently to address two study objectives: 1) determine if the biological condition of streams in areas with MTM/VF operations is degraded relative to the condition of streams in unmined areas and 2) determine if there are additive biological impacts to streams where multiple valley fills are located. The results of these analyses, regarding the aquatic impacts of MTM/VF operations, are provided in this report for inclusion in the overall EIS.

ANALYTICAL APPROACH AND RESULTS

Fish Data Analyses and Results

The Mid-Atlantic Highlands Index of Biotic Integrity (IBI), was used in the analyses of the fish data. This index is made up of scores from multiple metrics that are responsive to stress. Each of the sites sampled was placed into one of six EIS classes (i.e., Unmined, Filled, Mined, Filled/Residential, Mined/Residential, Additive). Due to inadequate sample size, the Mined/Residential class was removed from analyses. The Additive class was analyzed separately because it was made up of sites that were potentially influenced by multiple sources of stress.

The objective of the IBI analyses were to examine and compare EIS classes to determine if they are associated with the biological condition of streams. The distributions of IBI scores showed that the Filled and Mined classes had lower overall IBI scores than the other EIS classes. The Filled/Residential class had higher IBI scores than the Filled or Mined classes. The combined Filled/Residential class and the Unmined class had median scores that were similar to regional reference sites. Unmined and regional reference sites were primarily in the "fair" range and a majority of the Filled/Residential sites fell within the "good" range.

A standard Analysis of Variance (ANOVA) was used to test for differences among EIS classes and the Least Square (LS) Means procedure using Dunnett's adjustment for multiple comparisons tested whether the Filled, Filled/Residential, and Mined EIS classes were significantly different ($p < 0.01$) from the Unmined class. The ANOVA showed that there were significant differences among EIS classes. The LS Means test showed that the IBI scores from Filled and Mined sites were significantly lower than the IBI scores from Unmined sites, and the IBI scores from Filled/ Residential sites were significantly higher than the IBI scores from Unmined sites. Of the nine metrics in the IBI, only the Number of Minnow Species and the Number of Benthic Invertivore Species were significantly different in the Unmined class. Therefore, it was determined that the primary causes of reduced IBI scores in Filled and Mined sites were the reductions in these two metrics relative to the Unmined sites.

It was found that Filled, Mined, and Filled/Residential sites in watersheds with areas greater than 10 km^2 had "fair" to "good" IBI scores, while Filled and Mined sites in watersheds with areas less than 10 km^2 often had "poor" IBI scores. Of the 14 sites Filled and Mined) in watersheds with areas greater than 10 km^2, four were rated "fair" and ten were rated "good" or better. Of the 17 sites (Filled and Mined) in watersheds with areas less than 10 km^2, only three were rated "fair" and 14 were rated "poor". The effects of fills were statistically stronger in watersheds with areas less than 10 km^2. Filled sites had IBI scores that were an average of 14 points lower than Unmined sites. It is possible that the larger watersheds act to buffer the effects of stress.

Additive sites were considered to be subject to multiple, and possibly cumulative, sources, and were not included in the analysis of the EIS classes reported above. From the additive analysis, it was determined that the Twelvepole Creek Watershed, in which the land use was mixed residential and mining, had “fair” IBI scores in most samples, and there are no apparent additive effects of the land uses in the downstream reaches of the watershed. Also, Twentymile Creek, which has only mining-related land uses, may experience impacts from the Peachorchard tributary. The IBI scores appear to decrease immediately downstream of the confluence of the two creeks, whereas above the confluence, IBI scores in the Twentymile Creek are higher than in the Peachorchard Creek. Peachorchard Creek may contribute contaminants or sediments to Twentymile Creek, causing degradation of the Twentymile IBI scores downstream of Peachorchard Creek.

The correlations between IBI scores and potential stressors detectable in water were examined. Zinc, sodium, nickel, chromium, sulfate, and total dissolved solids were associated with reduced IBI scores. However, these correlations do not imply causal relationships between the water quality parameters and fish community condition.

Macroinvertebrate Data Analyses and Results

The benthic macroinvertebrate data were analyzed for statistical differences among EIS classes. Macroinvertebrate data were described using the WVSCI and its component metrics. The richness metrics and the WVSCI were rarefied to 100 organisms to adjust for sampling effort. Four EIS classes (i.e.; Unmined, Filled, Mined, and Filled/Residential) were compared using one-way ANOVAs. Significant differences among EIS classes were followed by the Least Square (LS) Means procedure using Dunnett's adjustment for multiple comparisons to test whether the Filled, Filled/Residential, and Mined EIS classes were significantly different ($p < 0.01$) from the Unmined class. Comparisons were made for each of the sampling seasons where there were sufficient numbers of samples.

The results of the macroinvertebrate analyses showed significant differences among EIS classes for the WVSCI and some of its component metrics in all seasons except autumn 2000. Differences in the WVSCI were primarily due to lower Total Taxa, especially for mayflies, stoneflies, and caddisflies, in the Filled and Filled/Residential EIS classes. Sites in the Filled/Residential EIS class usually scored the worst of all EIS classes across all seasons.

Using the mean values for water chemistry parameters at each site, the relationships between WVSCI scores and water quality were determined. The strongest of these relationships were negative correlations between the WVSCI and measures of individual and combined ions. The WVSCI was also negatively correlated with the concentrations of Beryllium, Selenium, and Zinc.

Multiple sites on the mainstem of Twentymile Creek were identified as Additive sites and were included in an analysis to evaluate impacts of increased mining activities in the watershed across seasons and from upstream to downstream of the Twentymile Creek. Sites were sampled during four seasons. Pearson correlations between cumulative river kilometer and the WVSCI and it's component metrics were calculated. The number of metrics that showed significant correlations with distance along the mainstem increased across seasons. The WVSCI was significantly correlated with cumulative river kilometer in Winter 2000, Autumn 2000 and Winter 2001. For Winter 2001, a linear regression of the WVSCI with cumulative river kilometer indicated that the WVSCI decreased approximately one point upstream to downstream for every river kilometer.

MAJOR FINDINGS AND SIGNIFICANCE

Fish Data Findings and Significance

It was determined that IBI scores were significantly reduced at Filled sites compared to Unmined sites by an average of 10 points, indicating that fish communities were degraded below VFs. The IBI scores were similarly reduced at sites receiving drainage from historic mining or contour mining (i.e., Mined sites) compared to Unmined sites. Nearly all Filled and Mined sites with catchment areas smaller than 10 km^2 had "poor" IBI scores. At these sites, IBI scores from Filled sites were an average of 14 points lower than the IBI scores from Unmined sites. Filled and Mined sites with catchment areas larger than 10 km^2 had "fair" or "good" IBI scores. Most of the Filled/Residential sites were in these larger watersheds and tended to have "fair" or "good" IBI scores.

It was also determined that the Twelvepole Creek Watershed, which had a mix of residential and mining land uses, had "fair" IBI scores in most samples; there were no apparent additive effects of the land uses in the downstream reaches of the watershed. Twentymile Creek, which had only mining-related land uses, had "good" IBI scores upstream of its confluence with Peachorchard Creek, and "fair" and "poor" scores for several miles downstream of its confluence with Peachorchard Creek. Peachorchard Creek had "poor" IBI scores, and may have contributed to the degradation of the Twentymile Creek's IBI scores downstream of their confluence.

Macroinvertebrate Data Findings and Significance

The macroinvertebrate analyses showed significant differences among EIS classes for the WVSCI and some of its metrics in all seasons except autumn 2000. Differences in the WVSCI were primarily due to lower Total Taxa and lower EPT Taxa in the Filled and Filled/Residential EIS classes. Sites in the Filled/Residential EIS class usually had the lowest scores of all EIS classes across all seasons. It was not determined why the Filled/Residential class scored worse than the Filled class alone. U.S. EPA (2001 Draft) found the highest concentrations of sodium in the Filled/Residential EIS class, which may have negatively impacted these sites compared to those in the Filled class.

When the results for Filled and Unmined sites alone were examined, significant differences were observed in all seasons except autumn 1999 and autumn 2000. The lack of differences between Unmined and Filled sites in autumn 1999 was due to a decrease in Total Taxa and EPT Taxa at Unmined sites relative to the summer 1999. These declines in taxa richness metrics in Unmined sites were likely the result of drought conditions. Despite the relatively drier conditions in Unmined sites during autumn 1999, WVSCI scores and EPT Taxa richness increased in later seasons to levels seen in the spring 1999, whereas values for Filled sites stayed relatively low.

In general, statistical differences between the Unmined and Filled EIS classes corresponded to ecological differences between classes based on mean WVSCI scores. Unmined sites scored “very good” in all seasons except autumn 1999 when the condition was scored as “good”. The conditions at Filled sites ranged from “fair” to “good”. However, Filled sites that scored “good” on average only represented conditions in the Twentymile Creek watershed in two seasons (i.e., autumn 2000 and winter 2001). These sites are not representative of the entire MTM/VF study area. On average, Filled sites had lower WVSCI scores than Unmined sites.

The consistently higher WVSCI scores and the Total Taxa in the Unmined sites relative to Filled sites across six seasons showed that Filled sites have lower biotic integrity than sites without VFs. Furthermore, reduced taxa richness in Filled sites is primarily the result of fewer pollution-sensitive EPT taxa. The lack of significant differences between these two EIS classes in autumn 1999 appears to be due to the effects of greatly reduced flow in Unmined sites during a severe drought. Continued sampling at Unmined and Filled sites would improve the understanding of whether MTM/VF activities are associated with seasonal variation in benthic macroinvertebrate metrics and base-flow hydrology.

Examination of the Additive sites from the mainstem of Twentymile Creek indicated that impacts to the benthic macroinvertebrate communities increased across seasons and upstream to downstream of Twentymile Creek. In the first sampling season one metric, Total Taxa, was negatively correlated with distance along the mainstem. The number of metrics showing a relationship with cumulative river mile increased across seasons, with four of the six metrics having significant correlations in the final sampling season, Winter 2001. Also in Winter of 2001, a regression of the WVSCI versus cumulative river kilometer estimates a decrease of approximately one point in the WVSCI for each river kilometer. Season and cumulative river kilometer in this dataset may be surrogates for increased mining activity in the watershed.

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1. INTRODUCTION

1.1. Background

Since the early 1990s, the nature and extent of coal mining operations in the Appalachian Region of the U.S. have changed. An increased number of large (> 1,200-ha) surface mines have been proposed and technology has allowed for the expanded role of Mountaintop Mining (MTM) and Valley Fill (VF) operations. In these operations, the tops of mountains are removed in order to make the underlying coal accessible (Figure 1-1). The excess materials from the mountaintop removals typically have been deposited into adjacent valleys and their stream corridors (Figure 1-2). These depositions cover perennial streams, wetlands and tracts of wildlife habitat. Given the increased number of mines and the increased scale of mining operations in the MTM/VF Region, it has become necessary for federal and state agencies to ensure that the relevant regulations, policies, procedures and guidance adequately consider the potential individual and cumulative impacts that may result from these projects (U.S. EPA 1999).

1.2. Environmental Impact Statement Development

The U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers (COE), U.S. Office of Surface Mining (OSM), and U.S. Fish and Wildlife Service (FWS), in cooperation with the West Virginia Department of Environmental Protection (DEP), are preparing an Environmental Impact Statement (EIS) concerning the MTM/VF activities in West Virginia. The purpose of developing the EIS is to facilitate the informed consideration of the development of policies, guidance and coordinated agency decision-making processes to minimize, to the greatest extent practicable, the adverse environmental effects to the waters, fish and wildlife resources in the U.S. from MTM operations, and to other environmental resources that could be affected by the size and location of fill material in VF sites (U.S. EPA 2001). Additionally, The EIS will determine the proposed action, and develop and evaluate a range of reasonable alternatives to the proposed action.

The goals of the EIS are to: (1) achieve the purposes stated above; (2) assess the mining practices currently being used in West Virginia; (3) assess the additive effects of MTM/VF operations; (4) clarify the alternatives to MTM; (5) make environmental evaluations of individual mining projects; (6) improve the capacity of mining operations, regulatory agencies, environmental groups and land owners to make informed decisions; and (7) design improved regulatory tools (U.S. EPA 2000). The major components of the EIS will include: human and

Figure 1-1. A MTM operation in West Virginia. The purpose of these operations are to remove mountaintops in order to make the underlying coal accessible.

Figure 1-2. A VF in operation. The excess materials from a MTM operation are being placed in this adjacent valley.

community impacts (i.e., quality of life, economic), terrestrial impacts (i.e., visuals, landscape, biota), aquatic impacts and miscellaneous impacts (i.e., blasting, mitigation, air quality).

1.3. Aquatic Impacts Portion of the EIS

The U.S. EPA's Region 3 initiated an aquatic impacts study to support the EIS. From the spring (i.e., April to June) 1999 through the winter (i.e., January to March) 2000, the U.S. EPA Region 3 collected data from streams within the MTM/VF Region. These data include water chemistry, habitat, and macroinvertebrates. With cooperation and guidance from the U.S. EPA Region 3, the Pennsylvania State University's (PSU's) School of Forest Resources collected fish data from streams in the MTM/VF Region. In addition to the data that were collected by the U.S. EPA Region 3 and PSU, data were also collected by three environmental consulting firms, representing four coal mining companies. These environmental consulting firms were Biological Monitoring, Incorporated (BMI); Potesta & Associates, Incorporated (POTESTA); and Research, Environmental, and Industrial Consultants, Incorporated (REIC).

Three reports which describe the data collected by the U.S. EPA Region 3 and PSU's School of Forest Resources were prepared. The first report summarized the condition of streams in the MTM/VF Region based on the macroinvertebrate data that were collected (Green et al. 2000 Draft). This report provided a descriptive analysis of the macroinvertebrate data. The second report described the fish populations in the MTM/VF Region based on the fish data collected by the PSU's School of Forest Resources (Stauffer and Ferreri 2000 Draft). This report used a fish index that was developed by the Ohio EPA for larger streams. The third report was a survey of the water quality of streams in the MTM/VF Region based on the water chemistry data collected by the U.S. EPA Region 3 (U.S. EPA 2002 Draft).

1.4. Scope and Objectives of This Report

In this document, the National Exposure Research Laboratory (NERL) of the U.S. EPA's Office of Research and Development (ORD) has assembled a database of Region 3, PSU and environmental consulting firm data collected from the MTM/VF Region. Using this combined data set, NERL analyzed fish and macroinvertebrate data separately to address the study's objectives. The results of these analyses will allow NERL to provide a report on the aquatic impacts of the MTM/VF operations for inclusion in the EIS.

The objectives of this document are to: 1) determine if the biological condition of streams in areas with MTM/VF operations is degraded relative to the condition of streams in unmined areas and 2) determine if there are additive biological impacts in streams where multiple VFs are located.

1.5. Biological Indices

One of the ways in which biological condition is assessed is through the use of biological indices. Biological indices allow stream communities to be compared by using their diversity, composition and functional organization. The use of biological indices is recommended by the Biological Criteria portion of the U.S. EPA's National Program Guidance for Surface Waters (U.S. EPA 1990). As of 1995, 42 states were using biological indices to assess impacts to streams (U.S. EPA 1996).

Two indices were identified as being appropriate for use with data collected from the MTM/VF Region. These were the Mid-Atlantic Highlands Index of Biotic Integrity (IBI) for fish (McCormick et al. 2001) and the West Virginia Stream Condition Index (WVSCI) for invertebrates (Gerritsen et al. 2000).

Due to the lack of a state developed fish index for West Virginia, an index created for use in the Mid-Atlantic Highlands was selected for evaluation of the fish data. The Mid-Atlantic Highlands IBI (McCormick et al. 2001) was developed using bioassessment data collected by the U.S. EPA from 309 wadeable streams from 1993 to 1996 in the Mid-Atlantic Highlands portion of the U.S. These data were collected using the U.S.

EPA's Environmental Monitoring and Assessment Program (EMAP) protocols (Lazorchak et al. 1998). Site selection was randomly stratified. Fish were collected within reaches whose lengths were 40 times the wetted width of the stream with minimum and maximum reach lengths being 150 and 500 m, respectively. All fish collected for these bioassessments were identified to the species taxonomic level. An Analysis of Variance (ANOVA) showed that there were no differences between the ecoregions in which the data were collected. A subset of the data was used to develop the IBI and another subset was used to validate the IBI and its component metrics. Fifty-eight candidate metrics were evaluated. Of these, 13 were rejected because they did not demonstrate an adequate range, two were rejected because they had excessive signal-to-noise ratios, three were rejected because they were redundant with other metrics, one was rejected because it remained correlated with watershed area after it had been adjusted to compensate for area and 30 were rejected because they were not significantly correlated with anthropogenic impacts. The remaining nine metrics used in the IBI are described in Table 1-2 (McCormick et al. 2001). All metrics were scored on a continuous scale from 0 to 10. Three sets of reference condition criteria (i.e., least restrictive, moderately restrictive, most restrictive) were used to determine the threshold values for the metrics. For the metrics which decrease with perturbation (Table 1-1), a score of 0 was given if the value was less than the 5th percentile of the values from non-reference sites and a score of 10 was given if the value was greater than the 50th percentile of the values from reference sites defined by the most restrictive criteria. For the metrics which increase with perturbation (Table 1-1), a score of 0 was given if the value was greater than the 90th percentile of the values from non-reference sites and a score of 10 was given if the value was less than the 50th percentile of the values from reference sites defined by the moderately restrictive criteria. The IBI scores were scaled from 0 to 100 by summing the scores from the nine metrics and multiplying this sum by 1.11.

Table 1-1. The nine metrics in the Mid-Atlantic Highlands IBI, their definitions and their expected responses to perturbations.

Metric	Metric Description	Predicted Response to Stress
Native Intolerant Taxa	Number of indigenous taxa that are sensitive to pollution; adjusted for drainage area	Decrease
Native Cyprinidae Taxa	Number of indigenous taxa in the family Cyprinidae (carps and minnows); adjusted for drainage area	Decrease
Native Benthic Invertivores	Number of indigenous bottom dwelling taxa that consume invertebrates; adjusted for drainage area	Decrease
Percent Cottidae	Percent individuals of the family Cottidae (i.e., sculpins)	Decrease
Percent Gravel Spawners	Percent individuals that require clean gravel for reproductive success	Decrease

Percent Piscivore/Invertivores	Percent individuals that consume fish or invertebrates	Decrease
Percent Macro Omnivore	Percent individuals that are large and omnivorous	Increase
Percent Tolerant	Percent individuals that are tolerant of pollution	Increase
Percent Exotic	Percent individuals that are not indigenous	Increase

The WVSCI (Gerritsen et al. 2000) was developed using bioassessment data collected by the WVDEP from 720 sites in 1996 and 1997. These data were collected using the U.S. EPA's Rapid Bioassessment Protocols (RBP, Plafkin et al. 1989). From these bioassessments, 100 benthic macroinvertebrates were identified to the family taxonomic level from each sample. The information derived from the analyses of these data were used to establish appropriate site classifications for bioassessments, determine the seasonal differences among biological metrics, elucidate the appropriate metrics to be used in West Virginia and define the thresholds that indicate the degree of comparability of streams to a reference condition. The analyses of these data showed that there was no benefit to partitioning West Virginia into ecoregions for the purpose of bioassessment. The analyses also showed that variability in the data could be reduced by sampling only from late spring through early summer. Using water quality and habitat criteria, the reference and impaired sites were identified among the 720 sampled sites. Then, a suite of candidate metrics were evaluated based on their abilities to differentiate between reference and impaired sites, represent different aspects of the benthic macroinvertebrate community (i.e., composition, richness, tolerance), and minimize redundancy among individual component metrics. Based on these evaluations, it was determined that the metrics making up the WVSCI should be EPT taxa, Total taxa, % EPT, % Chironomidae, the Hilsenhoff Biotic Index (HBI) and % 2 Dominant taxa (Table 1-2). Next, the values for these metrics were calculated for all 720 sites and those values were standardized by converting them to a 0-to-100-point scale. The standardized scores for the six metrics were averaged for each site in order to obtain index scores. Data collected from West Virginia in 1998 were used to test the index. This analysis showed that the index was able to discriminate between reference and impaired sites (Gerritsen et al. 2000).

Table 1-2. The six metrics in the WVSCI, their definitions and their expected responses to perturbations.

Metric	Definition	Expected Response to Perturbation
EPT Taxa	The total number of EPT taxa.	Decrease
Total Taxa	The total number of taxa.	Decrease
% EPT	The percentage of the sample made up of EPT individuals.	Decrease

% Chironomidae	The percentage of the sample made up of Chironomidae individuals.	Increase
HBI	An index used to quantify an invertebrate assemblage's tolerance to organic pollution.	Increase
% 2 Dominant taxa	The percentage of the sample made up of the dominant two taxa in the sample.	Increase

2. METHODS AND MATERIALS

2.1. Data Collection

The U.S. EPA Region 3 collected benthic macroinvertebrate and habitat data from spring 1999 through spring 2000. These data were collected from 37 sites in five watersheds (i.e., Mud River, Spruce Fork, Clear Fork, Twentymile Creek, and Island Creek Watersheds) in the MTM/VF Region of West Virginia (Figure 2-1). Two sites were added to the study in spring 2000. These additions were a reference site not located near any mining activities and a supplementary site located near mining activities. Using these data, the U.S. EPA Region 3 developed a report (Green et al. 2000 Draft) which characterized the benthic macroinvertebrate assemblages in the MTM/VF Region of

West Virginia.

The PSU's School of Forest Resources collected fish data in the MTM/VF Region of West Virginia and Kentucky. These data were collected from 58 sites in West Virginia and from 15 sites in Kentucky. The data collected from the Kentucky sites will not be used in this document. All of PSU's West Virginia sites were located in the same five watersheds from which the U.S. EPA Region 3 collected benthic macroinvertebrate, habitat and water quality data and most of these sites were located near the locations from which the U.S. EPA Region 3 collected these data. Data were collected in autumn 1999 and spring 2000. The results of this study were reported by Stauffer and Ferreri (2000 Draft).

The U.S. EPA Region 3 collected water quality data and water samples for chemical analyses from October 1999 through February 2001. These data were collected from the same 37 sites from which the U.S. EPA Region 3 collected benthic macroinvertebrate and habitat data. Using these data, the U.S. EPA Region 3 developed a report (U.S. EPA 2002 Draft) which characterized the water quality of streams in the MTM/VF Region of West Virginia.

The environmental consulting firm, BMI, collected water quality, water chemistry, habitat, benthic macroinvertebrate and fish data in the MTM/VF Region of West Virginia. These data were collected for Arch Coal, Incorporated from 37 sites in the Twentymile Creek Watershed and for Massey Energy Company from 11 sites in the Island Creek Watershed.

In addition, the environmental consulting firm, REIC, collected water quality, water chemistry, habitat, benthic macroinvertebrate and fish data in the MTM/VF Region of West Virginia. These data were collected for the Penn Coal Corporation from 18 sites in the Twelvepole Creek Watershed. Although the Twelvepole Creek Watershed is not among the

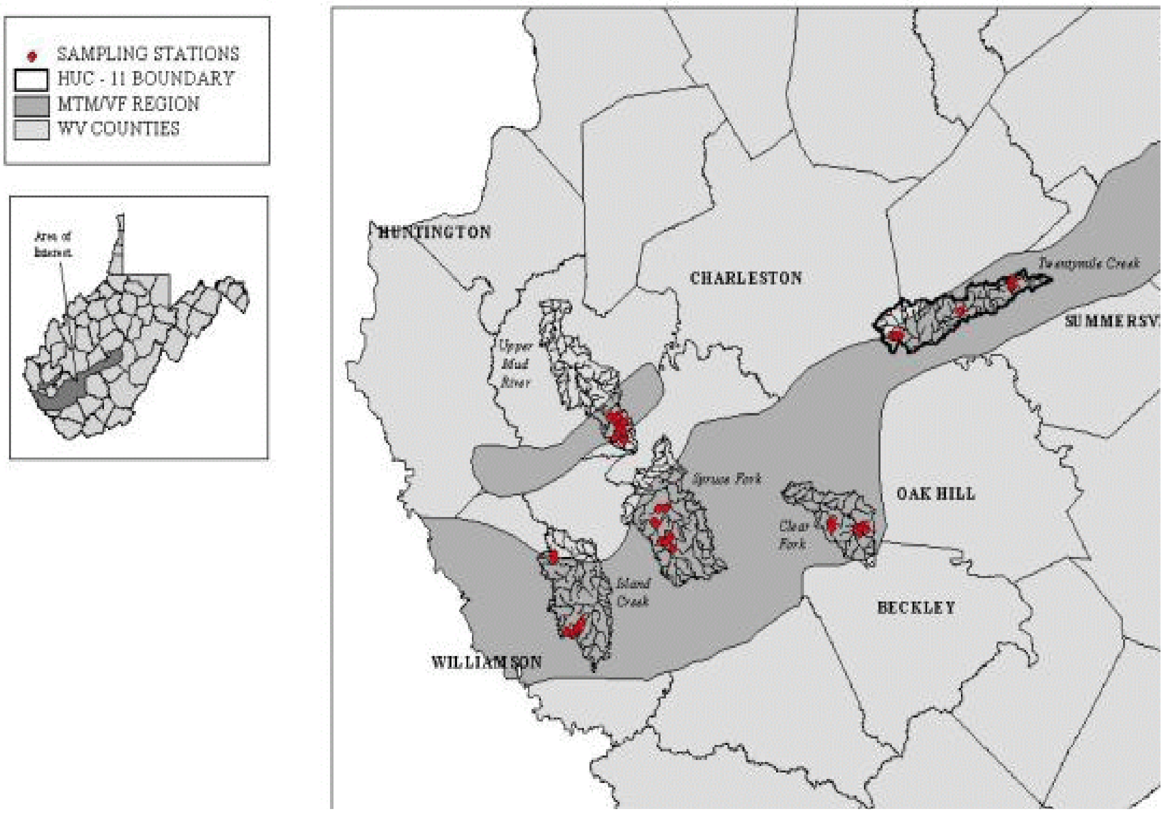


Figure 2-1. Study area for the aquatic impacts study of the MTM/VF Region of West Virginia.

watersheds from which the U.S. EPA Region 3 collected ecological data, some of these data will be considered in this report.

Finally, the environmental consulting firm, POTESTA, collected water quality, water chemistry, habitat, benthic macroinvertebrate, and fish data in the MTM/VF Region of West Virginia. These data were collected for the Fola Coal Company from ten sites in the Twentymile Creek Watershed (See Appendix E for a summary of benthic methods used by all groups).

2.2. Site Classes

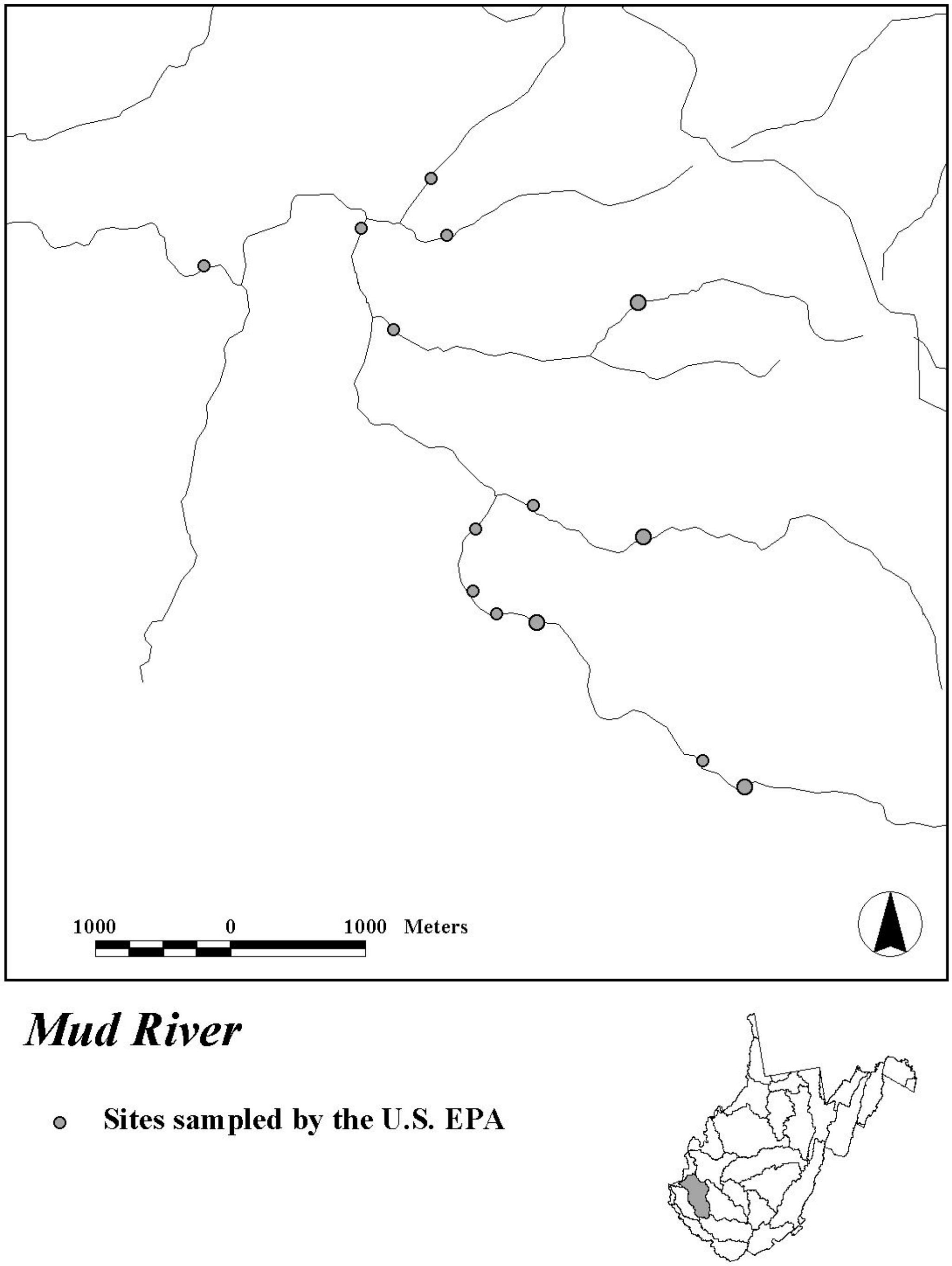
Each of the sites sampled by the U.S. EPA Region 3, PSU or one of the participating environmental consulting firms was placed in one of six classes. These six classes were: 1) Unmined, 2) Filled, 3) Mined, 4) Filled/Residential, 5) Mined/Residential and 6) Additive. The Unmined sites were located in areas where there had been no mining activities upstream. The Filled sites were located downstream of at least one VF. The Mined sites were located downstream of some mining activities but were not downstream of any VFs. The Filled/Residential sites were located downstream of at least one VF, and were also near residential areas. The Mined/Residential sites were located downstream of mining activity, and were also near residential areas. The additive sites were located on a mainstem of a watershed and were downstream of multiple VFs and VF-influenced streams.

2.3. Study Areas

2.3.1. Mud River Watershed

The headwaters of the Mud River are in Boone County, West Virginia, and flow northwest into Lincoln County, West Virginia. Although the headwaters of this watershed do not lie in the primary MTM/VF Region, there is a portion of the watershed that lies perpendicular to a five-mile strip of land in which mining activities are occurring. From the headwaters to the northwestern boundary of the primary MTM/VF Region, the watershed lies in the Cumberland Mountains of the Central Appalachian Plateau. The physiography is unglaciated, dissected hills and mountains with steep slopes and very narrow ridge tops and the geology is Pennsylvania sandstone, siltstone, shale, and coal of the Pottsville Group and Allegheny Formation (Woods et al. 1999). The primary land use is forest with extensive coal mining, logging, and gas wells. Some livestock farms and scattered towns exist in the wider valleys. Most of the low-density residential land use is concentrated in the narrow valleys (Green et al. 2000 Draft).

The U.S. EPA Region 3 sampled ten sites in the Mud River Watershed (Figure 2-2, Table 2-1). Brief descriptions of these sites are given below and more complete descriptions are given in Green et al. (2000 Draft). Site MT01 was established on the Mud River and the major disturbances at this site are a county road and residences. There also have been a few historical mining activities conducted upstream of site MT01. Site MT02 was established on Rush Patch Branch upstream of all residences and farms. While there is no history of mining in this sub-watershed, there is evidence of logging and gas well development. Site MT03 was established well above the mouth of Lukey Fork. Logging is the only known disturbance upstream of this site. Site MT13 was established on the Spring Branch of Ballard Fork. Other than historical logging activity, there is very little evidence of human disturbance associated with this site. Site MT14 was established on Ballard Fork. It is located downstream of eight VFs for which the mining permits were issued in 1985, 1988 and 1989. Site MT15 was established on Stanley Fork, located downstream of six VFs for which mining permits were issued in 1988, 1989, 1991, 1992 and 1995. Site MT24 was established in a sediment control structure on top of the mining operation located in the Stanley Fork sub-watershed. Site MT18 was established on Sugartree Branch. It was located downstream of two VFs for which the



mining permits were

Figure 2-2. Sites sampled in the Mud River Watershed.

Table 2-1. Sites sampled in the Mud River Watershed.

Site ID/Organization	Stream Name	EIS Class
U.S. EPA Region 3		

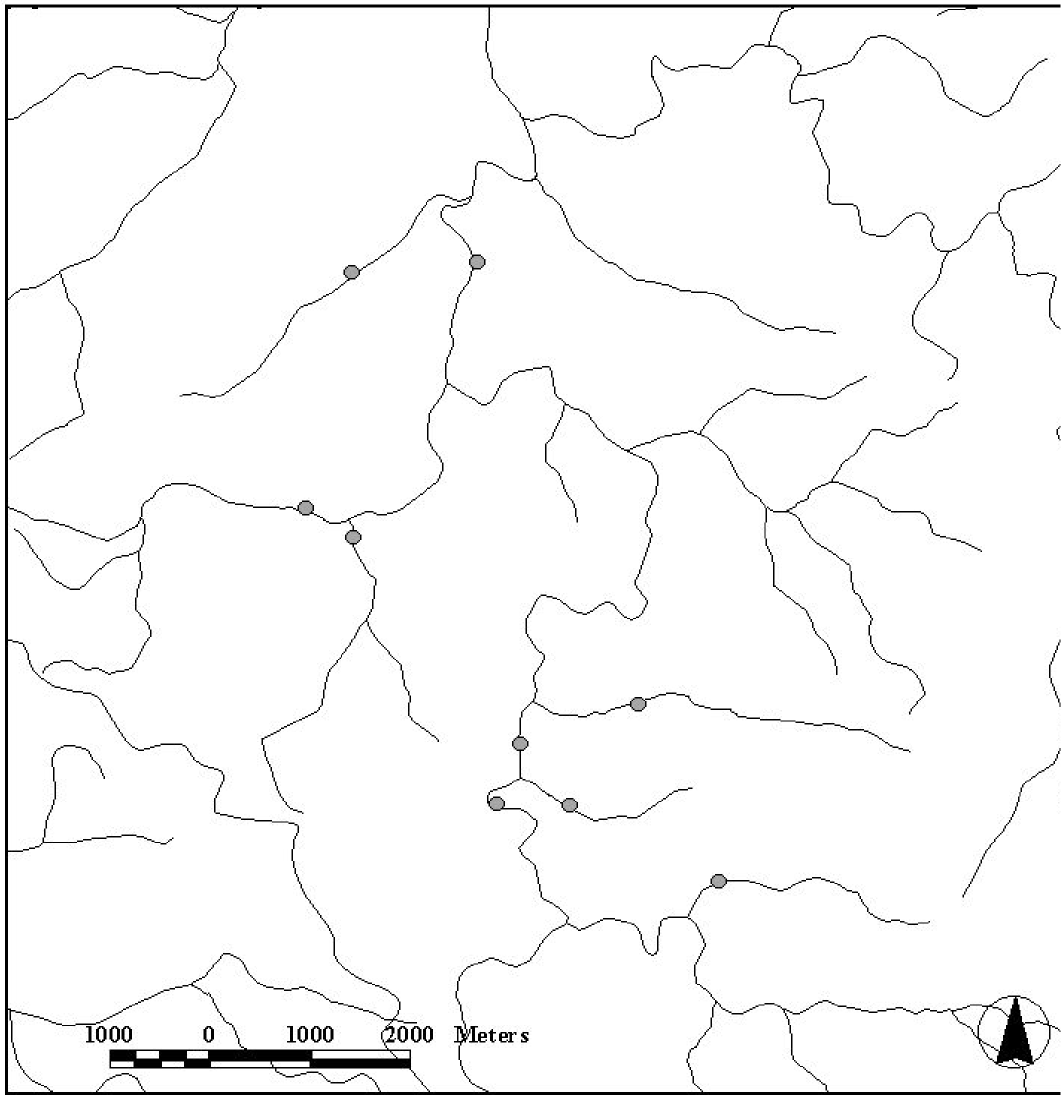
MT01	Mud River	Mined/Residential
MT02	Rushpatch Branch	Unmined
MT03	Lukey Fork	Unmined
MT13	Spring Branch	Unmined
MT14	Ballard Fork	Filled
MT15	Stanley Fork	Filled
MT24	Unnamed Trib. to Stanley Fork	Sediment Control Structure
MT18	Sugartree Branch	Filled
MT23	Mud River	Filled/Residential
MT16	Unnamed Trib. to Sugartree Branch	Mined

issued in 1992 and 1995. Site MT23 was established on the Mud River downstream of mining activities. These activities include active and inactive surface mines and one active underground mine. In the spring of 2000, Site MT16 was established on an unnamed tributary to Sugartree Branch. This site was downstream of historical surface mining activities, but was not downstream of any VFs (Green et al. 2000 Draft).

2.3.2. Spruce Fork Watershed

The Spruce Fork Watershed drains portions of Boone and Logan Counties, West Virginia. The stream flows in a northerly direction to the town of Madison, West Virginia where it joins Pond Fork to form the Little Coal River. Approximately 85 to 90% of the watershed resides in the primary MTM region. Only the northwest corner of the watershed lies outside of this region. The entire watershed lies in the Cumberland Mountains sub-ecoregion (Woods et al. 1999). The watershed has been the location of surface and underground mining for many years, therefore, much of the watershed has been disturbed (Green et al. 2000 Draft).

The U.S. EPA Region 3 sampled eight sites in the Spruce Fork Watershed (Figure 2-3, Table 2-2). Brief descriptions of these sites are given below and more complete descriptions are given in Green et al. (2000 Draft). The U.S. EPA Region 3 Site MT39 was established on White Oak Branch and no mining activities existed in this area. Site MT40 was established on Spruce Fork. It is located downstream of seven known surface mining VFs and three VFs associated with refuse disposal. Site MT42 was established on Oldhouse Branch, located upstream of all residences and there is no known history of mining activities in this area. Site MT45 was



Spruce Fork

Sites sampled by the U.S. EPA

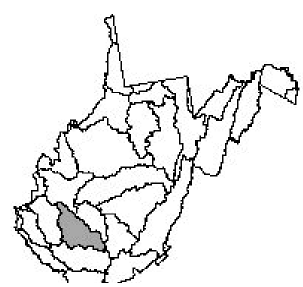


Figure 2-3. Sites sampled in the Spruce Fork Watershed.

Table 2-2. Sites sampled in the Spruce Fork Watershed.

Site ID/Organization	Stream Name	EIS Class
U.S. EPA Region 3		
MT39	White Oak Branch	Unmined

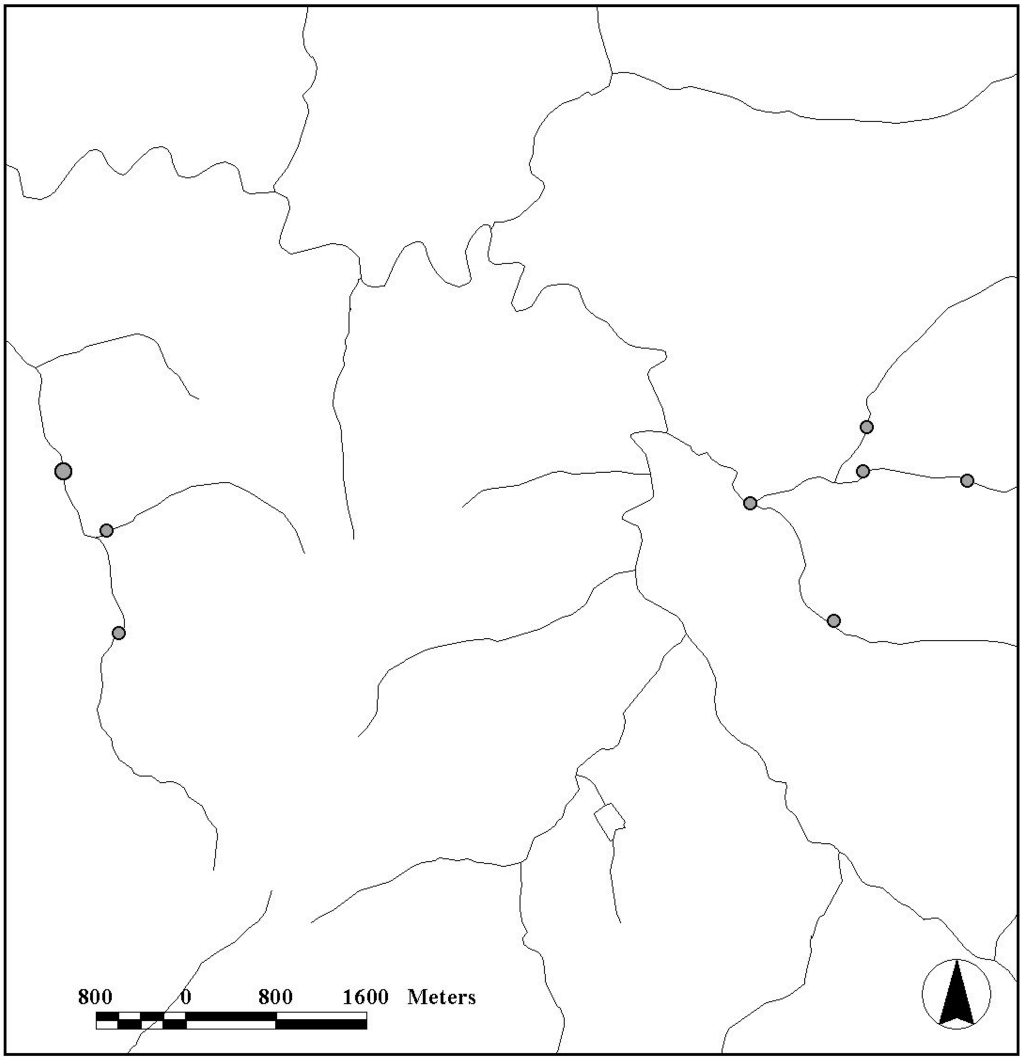
MT40	Spruce Fork	Filled/Residential
MT42	Oldhouse Branch	Unmined
MT45	Pigeonroost Branch	Mined
MT32	Beech Creek	Filled
MT34B	Left Fork	Filled
MT48	Spruce Fork	Filled/Residential
MT25B	Rockhouse Creek	Filled

established on Pigeonroost Branch. This site was located upstream of all residences but downstream of contour mining activities that occurred between 1987 and 1989. Site MT32 was established on Beech Creek. It was located downstream of five VFs and surface and underground mining activities. Site MT34B was established on the Left Fork of Beech Creek. It was located downstream of VFs and surface and underground mining activities. Site MT48 was established on Spruce Fork just upstream of Rockhouse Creek. There are known to be 22 VFs and several small communities upstream of this site. Site MT25B was established on Rockhouse Creek, located downstream of a sediment pond and a very large VF (Green et al. 2000 Draft).

2.3.3. Clear Fork Watershed

Clear Fork flows north toward its confluence with Marsh Fork where they form the Big Coal River near Whitesville, West Virginia. The entire watershed lies within Raleigh County, West Virginia within the Cumberland Mountains sub-ecoregion and, except for a very small portion, it lies within the primary MTM region (Woods et al. 1999). The coal mining industry has been active in this watershed for many years. Both surface and underground mining have occurred in the past and presently continue to be mined. There were no unmined sites sampled from this watershed (Green et al. 2000 Draft).

The U.S. EPA Region 3 sampled eight sites in the Clear Fork Watershed (Figure 2-4, Table 2-3). Brief descriptions of these sites are given below and more complete descriptions are given in Green et al. (2000 Draft). The U.S. EPA Region 3 Site MT79 was established on Davis Fork. It was located downstream of mining activities. Site MT78 was established on Raines Fork. It was located downstream of historical contour and underground mining. Site MT81 was



Clear Fork

● **Sites sampled by the U.S. EPA**

Figure 2-4. Sites sampled in the Clear Fork Watershed.

Table 2-3. Sites sampled in the Clear Fork Watershed.

Site ID/Organization	Stream Name	EIS Class
U.S. EPA Region 3		
MT79	Davis Fork	Mined

MT78	Raines Fork	Mined
MT81	Sycamore Creek	Mined
MT75	Toney Fork	Filled/Residential
MT70	Toney Fork	Filled/Residential
MT69	Ewing Fork	Mined/Residential
MT64	Buffalo Fork	Filled
MT62	Toney Fork	Filled/Residential

established on Sycamore Creek. It was located downstream of historical contour and underground mining and it is downstream of a plant that treats mine effluent. Site MT75 was established on Toney Fork. It was located downstream of five VFs, MTM activities and numerous residences. Site MT70 was established approximately 1 km (0.6 mi) downstream of Site MT75. It was located downstream of six VFs, MTM activities and numerous residences. This site was only sampled during autumn 1999 and winter and spring 2000. Site MT69 was established on Ewing Fork. It was located downstream of some historical contour and underground mining activities and a residence. Site MT64 was established on Buffalo Fork. It was located downstream of historical contour mining, current MTM activities, five VFs and a small amount of pasture. Site MT62 was established on Toney Fork. It was located downstream of 11 VFs, numerous residences and a small amount of pasture (Green et al. 2000 Draft).

2.3.4. Twentymile Creek Watershed

Twentymile Creek drains portions of Clay, Fayette, Kanawha, and Nicholas Counties, West Virginia. It generally flows to the southwest where it joins the Gauley River at Belva, West Virginia. Except for a small area on the western edge of the watershed, it is within the primary MTM region and the entire watershed lies within the Cumberland Mountains sub-ecoregion (Woods et al. 1999). Upstream of Vaughn, West Virginia, the watershed is uninhabited and logging, mining, and natural gas extracting are the primary activities. The majority of the mining activity has been conducted recently. Downstream of Vaughn, there are numerous residences and a few small communities (Green et al. 2000 Draft).

The U.S. EPA Region 3 sampled seven sites in the Twentymile Creek Watershed (Figure 2-5, Table 2-4). Brief descriptions of these sites are given below and more complete description

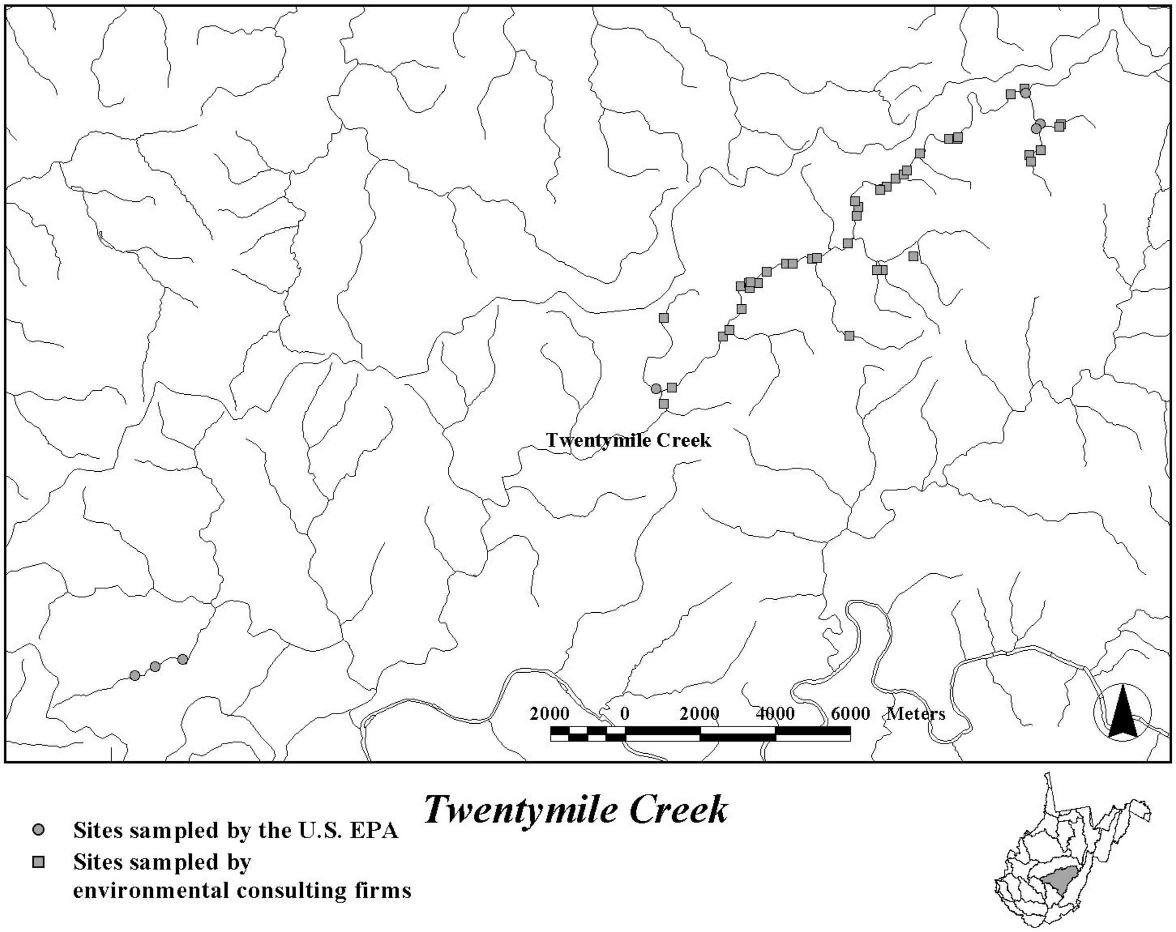


Figure 2-5. Sites sampled in the Twentymile Creek Watershed.

are given in Green et al. (2000 Draft). The U.S. EPA Region 3 Site MT95 was established on Neil Branch. There were no known disturbances upstream of this site. Site MT91 was established on Rader Fork. The only known disturbance to this site was a road with considerable coal truck traffic. Site MT87 was established on Neff Fork downstream of three VFs and a mine drainage treatment plant. Site MT86 was located on Rader Fork downstream of Site MT91 and Neff Fork and it was, therefore, downstream of three VFs and a mine drainage treatment plant. Site MT103 was established on Hughes Fork. It was downstream of six VFs. Site MT98 was established on Hughes Fork. It was downstream of Site MT103 and eight VFs. Site MT104 was established on Hughes Fork. It was downstream of Site MT103, Site MT98, eight VFs and a sediment pond (Green et al. 2000 Draft).

Table 2-4. Sites sampled in the Twentymile Creek Watershed. Equivalent sites are noted parenthetically.

Site ID/Organization	Stream Name	EIS Class
U.S. EPA Region 3		
MT95 (=Neil-5)	Neil Branch	Unmined
MT91	Rader Fork	Unmined
MT87 (=Rader-4)	Neff Fork	Filled
MT86 (=Rader-7)	Rader Fork	Filled
MT103	Hughes Fork	Filled
MT98	Hughes Fork	Filled
MT104	Hughes Fork	Filled
BMI		
Rader 8	Twentymile Creek	Additive
Rader 9	Twentymile Creek	Additive
PMC-TMC-36	Twentymile Creek	Additive
PMC-TMC-35	Twentymile Creek	Additive
PMC-TMC-34	Twentymile Creek	Additive
PMC-TMC-33	Twentymile Creek	Additive
PMC-TMC-31	Twentymile Creek	Additive
PMC-TMC-30	Twentymile Creek	Additive
PMC-TMC-29	Twentymile Creek	Additive
PMC-TMC-28	Twentymile Creek	Additive
PMC-TMC-27	Twentymile Creek	Additive
PMC-TMC-26	Twentymile Creek	Additive
PMC-7	Twentymile Creek	Additive
PMC-6	Twentymile Creek	Additive
PMC-5	Twentymile Creek	Additive
PMC-TMC-4	Twentymile Creek	Additive
PMC-TMC-5	Twentymile Creek	Additive
PMC-TMC-314	Twentymile Creek	Additive
PMC-TMC-2	Twentymile Creek	Additive
PMC-TMC-1	Twentymile Creek	Additive

Continued

Table 2-4. Continued.

Site ID/Organization	Stream Name	EIS Class
BMI (Continued)		
PMC-HWB-1	Twentymile Creek	Additive
PMC-HWB-2	Twentymile Creek	Additive
Neil-6 (=Fola 48)	Twentymile Creek	Additive
Neil-7 (=Fola 49)	Twentymile Creek	Additive
Neil-2 (=Fola 53)	Neil Branch	Unmined
Neil-5 (=MT95)	Neil Branch	Unmined
Rader-1	Laurel Run	Unmined
Rader-2	Rader Fork	Unmined
Rader-3	Trib. to Rader	Unmined
Rader-4 (=MT87)	Neff Fork	Filled (2)
Rader-5	Neff Fork	Filled (2)
Rader-6	Trib. to Neff	Filled (1)
Rader-7 (=MT86)	Rader Fork	Filled (2)
PMC-1	Sugarcamp Branch	Filled (1)
PMC-11	Right Fork	Filled (1)
PMC-12	Road Fork	Filled (1)
PMC-15	Tributary to Robinson Fork.	Filled (1)
POTESTA		
Fola 33	Twentymile Creek	Additive
Fola 36	Twentymile Creek	Additive
Fola 37	Twentymile Creek	Additive
Fola 38	Twentymile Creek	Additive
Fola 48 (=Neil-6)	Twentymile Creek	Additive
Fola 49 (=Neil-7)	Twentymile Creek	Additive
Fola 39	Peachorchard Branch	Filled (2 small)
Fola 40	Peachorchard Branch	Filled (1 small)
Fola 45	Peachorchard Branch	Unmined
Fola 53 (=Neil-2)	Neil Branch	Unmined

2.3.5. Island Creek Watershed

Island Creek generally flows north toward Logan, West Virginia where it enters the Guyandotte River. The entire watershed is confined to Logan County. With the exception of the northern portion, the watershed lies within the primary MTM region and the entire watershed lies within the Cumberland Mountains sub-ecoregion (Woods et al. 1999). Extensive underground mining has occurred in the watershed for many years. As the underground reserves have been depleted and the economics of the area have changed, surface mining has played a larger role in the watershed (Green et al. 2000 Draft).

The U.S. EPA Region 3 sampled eight sites in the Island Creek Watershed (Figure 2-6, Table 2-5). Brief descriptions of these sites are given below and more complete descriptions are given in Green et al. (2000 Draft). The U.S. EPA Region 3 Site MT50 was located on Cabin Branch in the headwaters of the sub-watershed and upstream of any disturbances. Site MT51 was also established on Cabin Branch located downstream of Site MT50 and a gas well. Site MT107 was established on Left Fork in the spring of 2000, located upstream of the influence of VFs. Site MT52 was established near the headwaters of Cow Creek. It was located upstream of VFs, but downstream of an underground mine entrance, a small VF and a sediment pond. Site MT57B was established on Hall Fork for sampling in the spring and summer 1999. It was located downstream of a sediment pond and a VF. In the autumn 1999, Site MT57 was established near the mouth of Hall fork. It was farther downstream than Site MT57B and was downstream of a sediment pond and a VF. Site MT60 was established on Left Fork, downstream of Site MT107. It was located downstream of two existing VFs and three proposed VFs. Site MT55 was established on Cow Creek, downstream of Site MT52. It was located downstream of four VFs associated with MTM, one VF associated with underground mining, residences, a log mill, orchards, vineyards, cattle, and a municipal sewage sludge disposal site (Green et al. 2000 Draft).

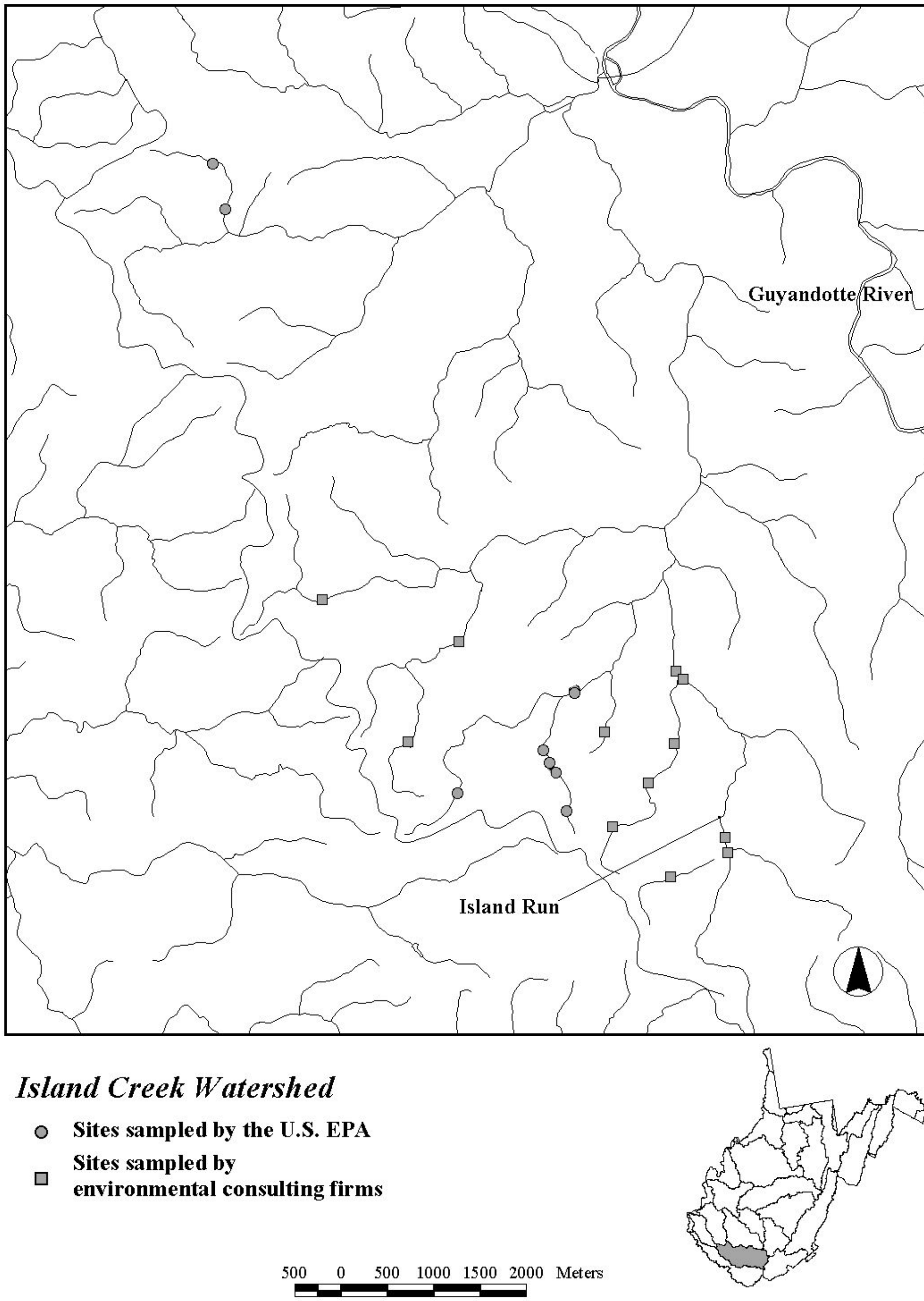

Guyandotte River
Island Run
Island Creek Watershed
Sites sampled by the U.S. EPA
Sites sampled by environmental consulting firms
500 0 500 1000 1500 2000 Meters

Figure 2-6. Sites sampled in the Island Creek Watershed.

Table 2-5. Sites sampled in the Island Creek Watershed.

Site ID/OrganizationStre	Stream Name	EIS Class
U.S. EPA Region 3 Sit		
MT50	Cabin Branch	Unmined

MT51	Cabin Branch	Unmined
MT107	Left Fork	Unmined
MT52	Cow Creek	Filled
MT57B	Hall Fork	Filled
MT57	Hall Fork	Filled
MT60	Left Fork	Filled
MT55	Cow Creek	Filled/Residential
BMI		
Mingo 34		Filled (1)
Mingo 41		Filled (2)
Mingo 39		Filled (1) + old mining
Mingo 16		Unmined
Mingo 11		Unmined
Mingo 2		Unmined
Mingo 86		Unmined
Mingo 62		Unmined
Mingo 38	Island Creek	Additive
Mingo 24	Island Creek	Additive
Mingo 23	Island Creek	Additive

2.3.6. Twelvepole Creek Watershed

The East Fork of the Twelvepole Creek Watershed drains portions of Mingo, Lincoln, and Wayne Counties, West Virginia. The stream flows northwest to the town of Wayne, West Virginia where it joins the West Fork of Twelvepole Creek then continues to flow on into the Ohio River at Huntington, West Virginia. The East Fork of Twelvepole Creek is impounded by East Lynn Lake near Kiahsville, West Virginia in Wayne County (West Virginia DEP, Personal Communication).

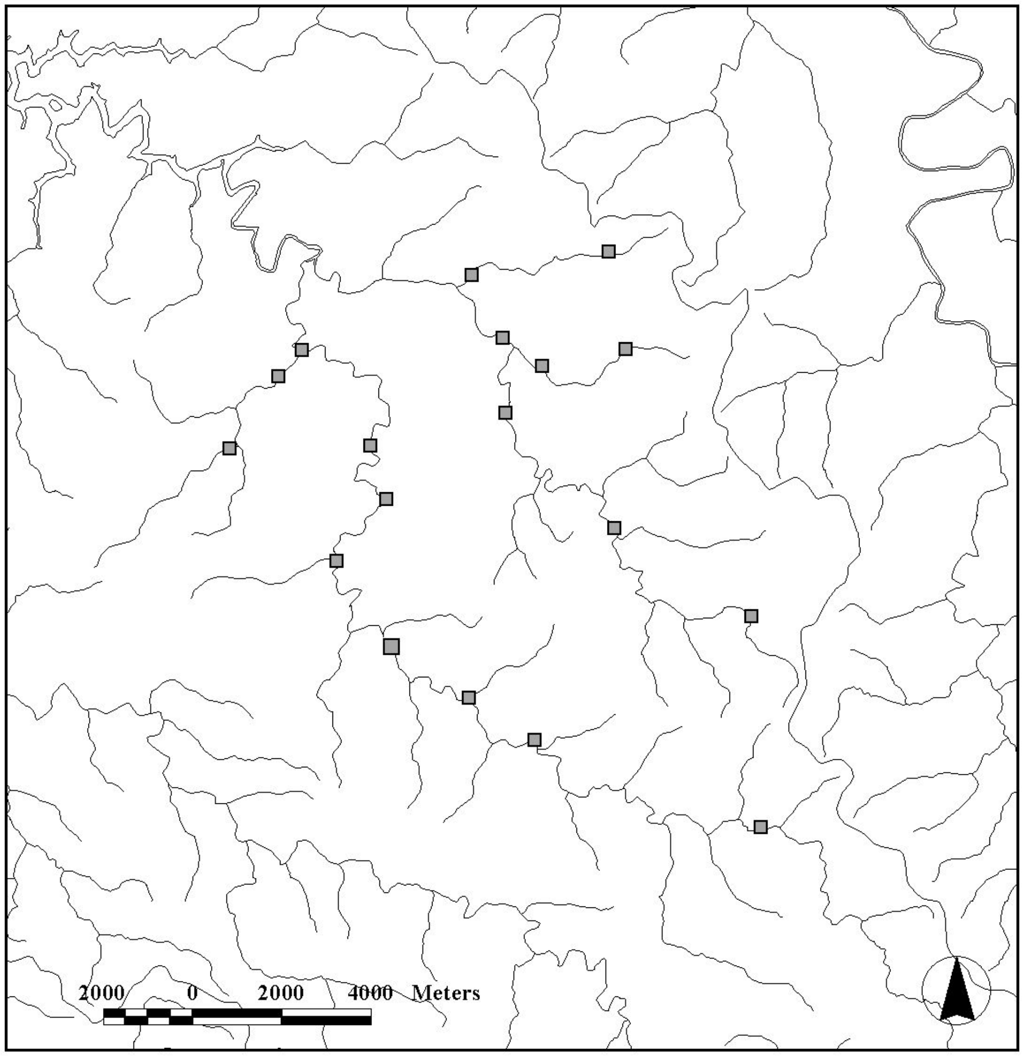
The East Fork of the Twelvepole Creek Watershed encompasses approximately 445 km^2 (172 mi^2) of drainage area and is 93.3% forested. Prior to 1977, very little mining had occurred in the watershed south of East Lynn Lake. Since 1987, several surface mining operations have been employed in the Kiah Creek and the East Fork of Twelvepole Creek watersheds (Critchley 2001). Currently, there are 23 underground mining, haul road and refuse site permits, and 21 surface mining permits in the watershed (West Virginia DEP, Personal Communication).

REIC has conducted biological evaluations in the East Fork of the Twelvepole Creek Watershed since 1995. Five stations have been sampled on Kiah Creek (Figure 2-7, Table 2-6). Station BM-003A was located in the headwaters of Kiah Creek, upstream from surface mining and residential disturbances. Station BM-003 was located near the border of Lincoln and Wayne Counties and it was downstream from several surface mining operations and several residential disturbances. Station BM-004 was located on Kiah Creek downstream from the surface mining operations on Queens Fork and Vance Branch, near the confluence of Jones Branch, downstream from Trough Fork, and downstream of residential disturbances. Station BM-004A was located downstream from the confluence of Big Laurel Creek, surface mining operations and residential disturbances.

Two stations were sampled in Big Laurel Creek (Figure 2-7, Table 2-6). This tributary has only residential disturbances in its watershed. Station BM-UBLC was located near the headwaters of Big Laurel Creek. Station BM-DBLC was located near the confluence of Big Laurel Creek with Kiah Creek.

Eight stations were sampled on the East Fork of Twelvepole Creek (Figure 2-7, Table 2-6). Station BM-001A was located just downstream from confluence of McCloud Branch and was downstream of a residential disturbance. Station BM-001C was located downstream of the confluence of Laurel Branch which currently has a VF, additional proposed VFs, and residences. Station BM-001B was located downstream of the confluence of Wiley Branch which has residences, numerous current VFs and additional VFs under construction or being proposed. Station BM-001 was located upstream from the confluence of Bluewater Branch but downstream from the Wiley Branch and Laurel Branch surface mining operations and residences. Station BM-010 was downstream from the Franks Branch mining operation and residences. Station BM-011 was located downstream from the Maynard Branch operations and residences. Station BM-002 was located downstream from the Devil Trace surface mining operation and residences. Station BM-002A was located downstream of Milam Creek and all mining operations and residences in this sub-watershed.

Two stations were located in Milam Creek, a tributary of the East Fork of Twelvepole Creek (Figure 2-7, Table 2-6). Milam Creek has no mining operations or residential disturbances in its watershed. Station BM-UMC was located near the headwaters of Milam Creek and station BM-DMC was located near the confluence of Milam Creek with the East Fork of Twelvepole Creek.



Twelvepole Creek

Sites sampled by environmental consulting firms

Figure 2-7. Sites sampled in the Twelvepole Creek Watershed.

Table 2-6. Sites sampled in the Twelvepole Creek Watershed. Equivalent sites are noted parenthetically.

Site ID/Organization	Stream Name	EIS Class
REIC		

BM-003A	Kiah Creek	Additive
BM-003	Kiah Creek	Additive
BM-004	Kiah Creek	Additive
BM-004A	Kiah Creek	Additive
BM-DBLC	Big Laurel Creek	Unmined
BM-UBLC	Big Laurel Creek	Unmined
BM-001A	Twelvepole Creek	Additive
BM-001C	Twelvepole Creek	Additive
BM-001B	Twelvepole Creek	Additive
BM-001	Twelvepole Creek	Additive
BM-010	Twelvepole Creek	Additive
BM-011	Twelvepole Creek	Additive
BM-002	Twelvepole Creek	Additive
BM-002A	Twelvepole Creek	Additive
BM-UMC	Milam Creek	Unmined
BM-DMC	Milam Creek	Unmined
BM-005	Trough Fork	Additive
BM-006	Trough Fork	Additive

2.4. Data Collection Methods

The data for this study were generated by five different organizations (i.e., U.S. EPA Region 3, PSU, BMI, POTESTA and REIC). The methods used to collect each of the four different types of data (i.e., habitat, water quality, fish assemblage and macroinvertebrate assemblage) are described below. This information is summarized in tabular form in Appendix A.

2.4.1. Habitat Assessment Methods

2.4.1.1. U.S. EPA Region 3 Habitat Assessment

The U.S. EPA Region 3 used the RBP (Barbour et al. 1999) to collect habitat data at each site. Although some parameters require observations of a broader section of the catchment area, the habitat data were primarily collected in a 100-m reach that includes the portion of the stream where biological data (i.e., fish and macroinvertebrate samples) were collected. The RBP habitat assessment evaluates ten parameters (Appendix A).

The U.S. EPA Region 3 measured substrate size and composition in order to help determine if excessive sediment was causing any biological impairments (Kaufmann and Robison 1998). Numeric scores were assigned to the substrate classes that are proportional to the logarithm of the midpoint diameter of each size class (Appendix A).

2.4.1.2. BMI Habitat Assessment

The Standard Operating Procedures (SOPs) submitted by BMI make no mention of habitat assessment methods.

2.4.1.3. POTESTA Habitat Assessment

POTESTA collected physical habitat data using methods outlined in Kaufmann et al. (1999) or in Barbour et al. (1999, Appendix A). The habitat assessments were performed on the same reaches from which biological sampling was conducted. A single habitat assessment form was completed for each sampling site. This assessment form incorporated features of the selected sampling reach as well as selected features outside the reach but within the catchment area. Habitat evaluations were first made on in-stream habitat, followed by channel morphology, bank structural features, and riparian vegetation.

2.4.1.4. REIC Habitat Assessment

The SOPs submitted by REIC make no mention of habitat assessment methods.

2.4.2. Water Quality Assessment Methods

2.4.2.1. U.S. EPA Water Quality Assessment

The U.S. EPA Region 3 measured conductivity, pH, temperature and dissolved oxygen (DO) *in situ* and the flow rate of the stream at the time of sampling. Each of these measurements was made once at each site during each field visit. The U.S. EPA Region 3 also collected water samples for laboratory analyses. These samples were analyzed for the parameters given in Table 2-7.

2.4.2.2. BMI Water Quality Assessment

The SOPs submitted by BMI make no mention of water quality assessment methods.

2.4.2.3. POTESTA Water Quality Assessment

POTESTA measured conductivity, pH, temperature and DO *in situ.* These measurements were taken once upstream from each biological sampling site, and were made following the protocols outlined in U.S. EPA (1979). The stream flow rate was also measured at or near each sampling point. One of the three procedures (i.e., velocity-area, time filling, or neutrally buoyant object) outlined in Kaufmann (1998) was used at each site. POTESTA also collected water samples at each site directly upstream of the location of the biological sampling. These samples were analyzed in the laboratory for the suite of analytes listed in Table 2-7.

2.4.2.4. REIC Water Quality Assessment

REIC recorded water body characteristics (i.e., size, depth and flow) and site location at each site. Grab samples were collected and delivered to the laboratory for analysis. The SOPs submitted by REIC make no mention of which analytes were measured in the laboratory.

2.4.3. Fish Assemblage Methods

2.4.3.1. PSU Fish Assemblage Assessment

The PSU, in consultation with personnel from U.S. EPA Region 3, sampled fish assemblages at 58 sites in West Virginia. The fish sampling procedures generally followed those in McCormick and Hughes (1998). Fish were collected by making three passes using a backpack electrofishing unit. Each pass proceeded from the downstream end of the reach to the upstream

Table 2-7. Parameters used by each organization for lab analyzed water samples.

Parameter	Organizations			
	U.S. EPA	BMI	POTESTA	REIC
Acidity	Yes	Unknown	Yes	Unknown
Alkalinity	Yes	Unknown	Yes	Unknown
Chloride	Yes	Unknown	Yes	Unknown
Hardness	Yes	Unknown	Yes	Unknown
Nitrate(NO_3) + Nitrite (NO_2)	Yes	Unknown	Yes	Unknown
Sulfate	Yes	Unknown	Yes	Unknown
Total Suspended Solids (TSS)	Yes	Unknown	Yes	Unknown
Total Dissolved Solids (TDS)	Yes	Unknown	Yes	Unknown
Total Organic Carbon (TOC)	Yes	Unknown	Yes	Unknown
Coarse Particulate Organic Matter (CPOM)	No	Unknown	Yes	Unknown
Fine Particulate Organic Matter (FPOM)	No	Unknown	Yes	Unknown
Total Dissolved Organic Carbon (TDOC)	Yes	Unknown	No	Unknown
Total Aluminum	Yes	Unknown	Yes	Unknown
Dissolved Aluminum	Yes	Unknown	Yes	Unknown
Total Antimony	Yes	Unknown	Yes	Unknown
Total Arsenic	Yes	Unknown	Yes	Unknown
Total Barium	Yes	Unknown	No	Unknown
Total Beryllium	Yes	Unknown	Yes	Unknown
Total Cadmium	Yes	Unknown	Yes	Unknown
Total Calcium	Yes	Unknown	Yes	Unknown
Total Chromium	Yes	Unknown	Yes	Unknown
Total Cobalt	Yes	Unknown	No	Unknown
Total Copper	Yes	Unknown	Yes	Unknown
Total Iron	Yes	Unknown	Yes	Unknown

(Continued)

Table 2-7. Continued.

Parameter	Organizations			
	U.S. EPA	BMI	POTESTA	REIC
Dissolved Iron	Yes	Unknown	Yes	Unknown
Total Lead	Yes	Unknown	Yes	Unknown
Total Magnesium	Yes	Unknown	Yes	Unknown
Total Manganese	Yes	Unknown	Yes	Unknown
Dissolved Manganese	Yes	Unknown	Yes	Unknown
Total Mercury	Yes	Unknown	Yes	Unknown
Total Nickel	Yes	Unknown	Yes	Unknown
Total Potassium	Yes	Unknown	Yes	Unknown
Total Phosphorous	Yes	Unknown	Yes	Unknown
Total Selenium	Yes	Unknown	Yes	Unknown
Total Silver	Yes	Unknown	Yes	Unknown
Total Sodium	Yes	Unknown	Yes	Unknown
Total Thallium	Yes	Unknown	Yes	Unknown
Total Vanadium	Yes	Unknown	No	Unknown
Total Zinc	Yes	Unknown	Yes	Unknown

end of the reach. Block nets were used only when natural barriers (i.e., shallow riffles) were not present. The fish collected from each pass were kept separate. Fish were identified to the species level and enumerated. The standard length of each fish was measured to the nearest mm and each fish was weighed to the nearest 0.01 g.

2.4.3.2. BMI Fish Assemblage Assessment

The SOPs submitted by BMI make no mention of fish assemblage assessment methods.

2.4.3.3. POTESTA Fish Assemblage Assessment

POTESTA collected fish by using the three-pass depletion method of Van Deventer and Platts (1983) with a backpack electrofishing unit. Each of the three passes proceeded from the downstream end of the reach to the upstream end of the reach. The fish collected from each pass were kept separate. Additional passes were made if the numbers of fish did not decline during the two subsequent passes. Game fish and rare, threatened or candidate (RTC) fish species were identified, their total lengths were recorded to the nearest mm, and their weights were recorded to the nearest g. With the exception of small game and non-RTC fish, the captured fish were released. Small game fish and non-RTC fish that were collected during each pass were preserved separately and transported to the laboratory for analysis. Preserved fish were identified and weighed to the nearest g.

2.4.3.4. REIC Fish Assemblage Assessment Methods

REIC collected fish by setting block nets across the stream and perpendicular to the stream banks, then progressing upstream with a backpack electrofishing unit. The entire reach was surveyed three times. After each survey, all large fish were identified using guidelines given by Trautman (1981) and Stauffer et al. (1995). The total lengths of the fish were measured to the nearest mm and they were weighed to the nearest g. After all three passes were completed, the large fish were returned to the stream. Small fish which required microscopic verification of their identification were preserved and transported to the laboratory. Once in the laboratory, small fish were identified using guidelines given by Trautman (1981) and Stauffer et al. (1995). After identification, the total lengths of the fish were measured to the nearest mm, they were weighed to the nearest 0.1 g and their identifications were reconfirmed.

2.4.4. Macroinvertebrate Assemblage Methods

2.4.4.1. U.S. EPA Region 3 Macroinvertebrate Assemblage Assessment

The U.S. EPA's Region 3 used RBPs to assess benthic macroinvertebrate assemblages (Barbour et al. 1999). Samples were collected from riffles only. A 0.5 m wide rectangular dip net with 595-μm mesh was used to collect organisms in a 0.25 m^2 area upstream of the net. At each site, four samples were taken, and composited into a single sample, representing a total area sampled of approximately 1.0 m^2. The RBPs recommend the total area sampled to be 2.0 m^2 but that was reduced to 1.0 m^2 for this study due to the small size of the streams. Benthic macroinvertebrate samples were collected in each season except when there was not enough flow for sampling. Approximately 25% of the sites were sampled in replicate to provide information on within-season and within-site variability. These replicate samples were collected at the same time, usually from adjacent locations in the same riffle.

The samples collected by the U.S. EPA Region 3 were sub-sampled in the laboratory so that ↗ of the composite samples were picked. All organisms in the sub-sample were identified to the family level, except for oligochetes and leeches, which were identified to the class level. Organisms were identified using published taxonomic references (i.e., Pennak 1989, Pecharsky et al. 1990, Stewart and Stark 1993, Merritt and Cummins 1996, Westfall and May 1996, Wiggins 1998).

2.4.4.2. BMI Macroinvertebrate Assemblage Methods

BMI collected samples using a kick net with a 0.5 m width and a 600 μm mesh size. The net was held downstream of the 0.25 m^2 area that was to be sampled. All rocks and debris that were in the 0.25 m^2 area were scrubbed and rinsed into the net and removed from the sampling area. Then, the substrate in the 0.25 m^2 area was vigorously disturbed for 20 seconds. This process was repeated four times at each sampling site and the four samples were composited into a single sample.

BMI also collected samples using a 0.09 m^2 (1.0 ft^2) Surber sampler with a 600 μm mesh size. The frame of the sampler was placed on the stream bottom in the area that was to be sampled. All large rocks and debris that were in the 1.0-ft^2 frame were scrubbed and rinsed into the net and removed from the sampling area. Then, the substrate in the 1.0 ft^2 frame was vigorously disturbed for 20 seconds. In autumn 1999 and spring 2000, no samples were collected with Surber samplers. In autumn 2000, six Surber samples were collected at each site, and in spring 2001, four Surber samples were collected. All Surber samples were kept separate.

In the laboratory, the samples were rinsed using a sieve with 700 μm mesh. All macroinvertebrates in the samples were picked from the debris. Each organism was identified to the taxa level specified in the project study plan.

2.4.4.3. POTESTA Macroinvertebrate Assemblage Assessment

POTESTA collected samples of macroinvertebrates using a composite of four 600 μm mesh kick net samples and following the U.S. EPA's RBPs (Barbour et al. 1999). For each of the four kick net samples, all large debris within a 0.25 m^2 area upstream of the kick net were brushed into the net. Then, the substrate in the 0.25 m^2 area was disturbed for 20 seconds. Once all four kick net samples were collected, they were composited into a single labeled jar.

POTESTA used Surber samplers to collect macroinvertebrate samples at selected sites. Surber samples were always collected in conjunction with kick net samples. At sites selected for quantitative sampling, a Surber sampler was placed on the stream bottom in a manner so that all sides were flat against the stream bed. Large cobble and gravel within the frame were thoroughly brushed and the substrate within the frame was disturbed for a depth of up to 7.6 cm (3.0 in) with the handle of the brush. The sample was then placed in a labeled jar. The SOPs submitted by POTESTA make no mention of the area sampled or the number of samples collected with the Surber samplers.

In the laboratory, all organisms in the samples were identified by qualified freshwater macroinvertebrate taxonomists to the lowest practical taxonomic levels using Wiggins (1977), Stewart and Stark (1988), Pennak (1989) and Merritt and Cummins (1996). To ensure the quality of the identifications, 10% of all samples were re-picked and random identifications were reviewed.

2.4.4.4. REIC Macroinvertebrate Assemblage Assessment

REIC collected macroinvertebrate samples using a 600 μm mesh D-frame kick net. The kick net was positioned in the stream with the net outstretched with the cod end on the downstream side. The person using the net then used a brush to scrub any rocks within a 0.25 m^2 area in front of the net, sweeping dislodged material into the net. The person then either kicked up the substrate in the 0.25 m^2 area in front of the net or knelt and scrubbed the substrate in that area with one hand. The substrate was scrubbed or kicked for up to three minutes, with the discharged material being swept into the net. This procedure was repeated four times so that the total area sampled was approximately 1.0 m^2. Once collected, the four samples were composited into a single sample.

REIC also collected macroinvertebrate samples using Surber samplers with sampling areas of 0.09 m^2 (1 ft^2). These samplers were only used in areas where the water depth was less than 0.03 m (1 ft). The SOPs submitted by REIC make no mention of the mesh size used in the Surber samplers. The Surber sampler was placed in the stream, with the cod end of the net facing downstream. The substrate within the 1 ft^2 area was scrubbed for a period of up to three minutes and to a depth of approximately 7.62 cm (3 in). While being scrubbed, the dislodged material was swept into the net. After scrubbing was complete, rocks in the sampling area were checked for clinging macroinvertebrates. Once they had been removed, the material in the net was rinsed and the sample was deposited into a labeled sampling jar. Three Surber samples were collected at each site where they were used. These samples were not composited.

In the laboratory, REIC processed all samples individually. Samples were poured through a 250 μm sieve and rinsed with tap water. The sample was then split into quarters by placing it on a sub-sampling tray fitted with a 500 μm screen and spread evenly over the tray. The sample in the first quarter of the tray was removed, placed into petri dishes, and placed under a microscope so that all macroinvertebrates could be separated from the detritus. If too few organisms (this number is not specified in the SOPs submitted by REIC) were in the first quarter, then additional quarters were picked until enough organisms had been retrieved from the sample.

REIC used three experienced aquatic taxonomists to identify macroinvertebrates. They identified the organisms under microscopes to their lowest practical taxonomic level, usually Genus. Chironomids were often identified to the Family level and annelids were identified to the Class level. As taxonomic guides, REIC used Pennak (1989), Stewart and Stark (1993), Wiggins (1995), Merritt and Cummins (1996) and Westfall and May (1996).

3. DATA ANALYSES

3.1. Database Organization

3.1.1. Data Standardization

All of the methods used to collect and process fish samples were compatible, thus it was not necessary to standardize the fish data prior to analysis. However, there were differences among the methods used to collect and process the benthic macroinvertebrate data which made it necessary to standardize the macroinvertebrate data to eliminate potential biases before data analysis.

The benthic macroinvertebrate database was organized by sampling device (i.e., D-frame kick net or Surber sampler). Since not all organizations used Surber samplers and not all organizations that used Surber samplers employed the same methods (Section 2.4.4), Surber data were not used for the analyses in this report. All of the sampling organizations did use D-frame kick nets with comparable field methods to collect macroinvertebrate samples. Use of the data collected by D-frame kick net provides unbiased data with respect to the types, densities and relative abundances of organisms collected. However, while identifying organisms in the laboratory, the U.S. EPA sub-sampled 1/8 of the total material (with some exceptions noted in the data), REIC sub-sampled 1/4 of the total material (with some exceptions), and BMI and POTESTA counted the entire sample. To eliminate bias of the reported taxa richness data introduced by different sizes of sub-samples, all organism counts were standardized to a 1/8 sub-sample of the total original material. (Appendices A and E)

3.1.2. Database Description

3.1.2.1. Description of Fish Database

The fish database included 126 sampling events where the collection of a fish sample had been attempted and the location and watershed area were known. Of these, five were regional reference samples from Big Ugly Creek, outside of the study watersheds. Catchments with areas of less than 2.0 km^2 and samples with fewer than ten fish were excluded from the analysis (section 4.1.1). A summary of the remaining 99 samples is shown in Table 3-1.

The Mined/Residential EIS Class consisted of only two samples. Due to insufficient sample size for adequate statistical analysis, this class was eliminated.

Table 3-1. Number of fish sites and samples in the study area, by EIS class and watershed. The first numbers in the cells represent the number of sites and the numbers in parentheses represent the numbers of samples.

Watershed	Unmined	Filled	Mined	Filled/Res	Additive	Total
Mud River	3, (4)	4, (8)		1, (3)	1, (2)	9, (17)
Island Creek	1, (1)	2, (3)		2, (2)	2, (2)	7, (8)
Spruce Fork	1, (1)	3, (3)	1, (1)	3, (3)	1, (1)	9, (9)
Clear Fork		1, (1)	3, (3)	3, (3)		7, (7)
Twenty Mile Creek	5, (5)	7, (7)			7, (16)	19, (28)
Twelvepole Creek[1]	4, (6)				12, (24)	16, (30)
Total	14, (17)	17, (22)	4, (4)	9, (11)	23, (45)	67, (99)

[1]All sites in Twelvepole Creek were sampled by REIC; and were Additive and Unmined only.

3.1.2.2. Description of Macroinvertebrate Database

A total of 282 macroinvertebrate samples were collected from 66 sites in six watersheds (Table 3-2). The samples from sites in the Mined/Residential EIS class were removed from the analysis because there were too few sites (i.e., n < 3) to conduct statistical comparisons.

The U.S. EPA Region 3 collected a duplicate sample from the same site, on the same day, 42 different times, in five of the six sampled watersheds (i.e., no duplicate samples were taken from the Twelvepole Creek Watershed). The WVSCI, the total # of families, and the total number of EPT were highly correlated for duplicate samples (Table 3-3). Green et al. (2000) found similar results with raw metric scores. Because of these correlations and in order to avoid inflating the sample size, the only U.S. EPA Region 3 duplicate samples used for analyses were those that were labeled Replicate

Number 1.

One site in Twentymile Creek was sampled by more than one organization the same season (i.e., autumn 2000 and winter 2001). To avoid sample size inflation, the means of the sample values were used for each season, thereby reducing the total number of samples. The means were used instead of the values from one of the samples because the samples were collected between three and five weeks apart. The U.S. EPA and two other organizations sampled the same site in the autumn 1999 and the winter 2000. In this case, the U.S. EPA data were used because these data did not require making a correction for sub-sampling.

Table 3-2. Number of sites and D-frame kick net samples available in each watershed and in each EIS class.

	EIS Class											
	Unmined		**Filled**		**Filled/ Residential**		**Mined**		**Mined/ Residential [1]**		**Total**	
Watershed	Site	Samp	Site	Samp	Site	Samp	Site	Samp	Site	Samp	Site	Samp
Mud River	3	11	3	19	1	6	1	1	1	5	9	42
Island Creek	7	13	6	21	1	6	1	1	0	0	15	41
Spruce Fork	2	8	3	18	2	14	1	5	0	0	8	45
Clear Fork	0	0	1	8	3	12	3	12	1	7	8	39
Twentymile Creek	7	32	15	71	0	0	0	0	0	0	22	103
Twelvepole Creek	4	12	0	0	0	0	0	0	0	0	4	12
Total	23	76	28	137	7	38	6	19	2	12	66	282

[1]Because there were only two Mined/Residential sites, this EIS class was not used in any of the analyses for this report.

The samples taken from the Twelvepole Creek Watershed (four Unmined EIS class sites) were made up of a mix of D-frame kick net and Surber sampler data that were inseparable by sampler type. Therefore, these data could not be standardized and were removed from the EIS analysis for the D-frame kick net data set.

These data reduction procedures lowered the total number of D-frame kick net samples for EIS analysis from 282 (Table 3-2) to 215 (Table 3-4). The U.S. EPA Region 3 collected 150 (69.8%) of these samples and the other organizations collected 65 (30.2%) of these samples. Hence, these other organizations provided 43% more samples for analysis than the U.S. EPA Region 3 had collected. These samples also provided information from 23 additional sites in the Unmined, Filled, Filled/Residential, and Mined EIS classes. However, these additional samples were not distributed evenly across watersheds and EIS classes. Only the U.S. EPA Region 3 collected data from the Mud River, Spruce Fork, and Clear Fork Watersheds and the majority (85%) of the samples collected by the private organizations were collected from the Twentymile Creek Watershed. As a result, the additional data provided by the private organizations were skewed to conditions in the Twentymile Creek Watershed, especially for sites in the Filled EIS class. Furthermore, 100% of the data collected by the private organizations during autumn 2000 and winter 2001 were collected from the Twentymile Creek Watershed. Therefore, comparisons made using data that were collected during these two seasons do not represent conditions across the entire study area, and have less than half the number of samples that were collected during the other seasons.

Table 3-3. Correlation and significance values for the duplicate samples collected by the U.S. EPA Region 3 with the WVSCI and standardized WVSCI metrics.

Metric	R	p-value
Total Number of Families Rarefied to 100 individuals	0.863	<0.001
Total Number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) Families Rarefied to 100 individuals	0.897	<0.001
WVSCI Rarefied to 100 individuals	0.945	<0.001

Table 3-4. Number of sites and D-frame kick net samples used for comparing EIS classes after the data set had been reduced.

		EIS Class									
		Unmined		**Filled**		**Filled/ Residential**		**Mined**		Total	
Watershed		Site	Samp	Site	Samp	Site	Samp	Site	Samp	Site	Samp
Mud River	U.S. EPA	3	9	3	15	1	5	1	1	8	30
	Private	0	0	0	0	0	0	0	0	0	0
Island Creek	U.S. EPA	3	7	4	15	1	5	0	0	8	27
	Private	4	6	2	3	0	0	1	1	7	10
Spruce	U.S. EPA	2	7	3	13	2	10	1	5	8	35

Fork	Private	0	0	0	0	0	0	0	0	0	0
	U.S. EPA	0	0	1	5	3	10	3	9	7	24
Clear Fork	Private	0	0	0	0	0	0	0	0	0	0
	U.S. EPA	2	9	5	25	0	0	0	0	7	34
Twenty-mile Creek	Private	6	18	10	37	0	0	0	0	16	55
	U.S. EPA	10	32	16	73	7	30	6	15	38	150
Total	Private	10	24	12	40	0	0	1	1	23	65

3.2. Data Quality Assurance/Quality Control

The biological, water chemistry, and habitat data were received in a variety of formats. Data were exported from their original formats into the Ecological Data Application System (EDAS), a customized relational database application (Tetra Tech, Inc., 1999). The EDAS allows data to be aggregated and analyzed by customizing the pre-designed queries to calculate a variety of biological metrics and indices.

Throughout the process of exporting data, the original data sources were consulted for any questions or discrepancies that arose. First, the original electronic data files were consulted and proofread to ensure that the data had been migrated correctly from the original format into the EDAS database program. If the conflict could not be resolved in this manner, hard copies of data reports were consulted, or, as necessary, the mining companies and/or the organizations who had originally provided the data were consulted. As data were migrated, Quality Assurance/Quality Control (QA/QC) queries were used to check for import errors. If any mistakes were discovered as a result of one of these QA/QC queries, the entire batch was deleted, re-imported, and re-checked. After all the data from a given source had been migrated, a query was created which duplicated the original presentation of the data. This query was used to check for data manipulation errors. Ten percent of the original samples were checked at random. If the data failed this QC check, they were entirely deleted, re-imported, and subjected to the same QC routine until they were 100% correct.

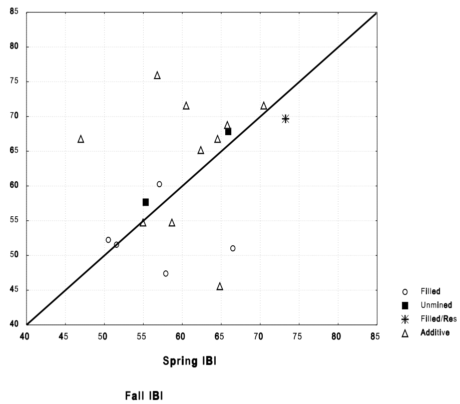
The EDAS contained separate Master Taxa tables for fish and benthic macroinvertebrates. Both Master Taxa tables contained a unique record for each taxonomic name, along with its associated ecological characteristics (i.e., preferred habitat, tolerance to pollution). To ensure consistency, Master Taxa lists were generated from all of the imported MTM/VF data. Taxonomic names were checked against expert sources, such as Merritt and Cummins (1996), Robins et al. (1991) and the online taxonomic database, Integrated Taxonomic Information System (ITIS, www.itis.usda.gov). Discrepancies and variations in spellings of taxonomic names were identified and corrected in all associated samples. Any obsolete scientific names were updated to the current naming convention to ensure consistency among all the data. Each taxon's associated ecological characteristics were also verified to assure QC for biological metrics generated from that ecological information. Different organizations provided data at different levels of taxonomic resolution. Because the WVSCI utilizes benthic information at the Family level, the benthic macroinvertebrate Master Taxa table was used to collapse all of the data to the Family level for consistency in analysis.

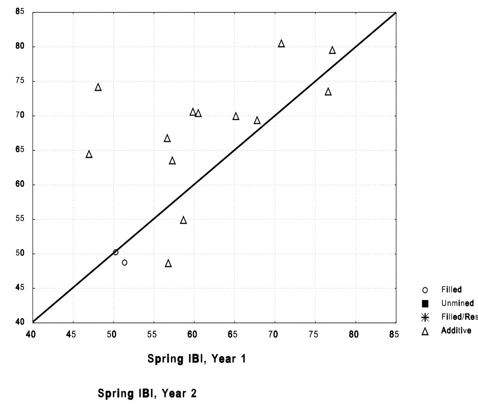
Minimum Detection Limits (MDLs) represent the smallest amount of an analyte that can be detected by a given chemical analysis method. While some methods are very sensitive and, therefore, can detect very small quantities of a particular analyte, other methods are less sensitive and have higher MDLs. When an analytical laboratory is unable to detect an analyte, the value is reported as "Below Detection", and the MDL is given. For the purpose of statistical analysis, the "Below Detection" values were converted to ½ of the methods' MDLs.

3.3. Summary of Analyses

The fish database and the macroinvertebrate database were analyzed separately to: 1) determine if the biological condition of streams in areas with MTM/VF operations is degraded relative to the condition of streams in unmined areas and 2) determine if there are additive biological impacts to streams where multiple valley fills are located. The statistical approach to evaluate these two objectives was the same for fish and macroinvertebrates. To address the first objective, EIS classes (Filled, Filled/Residence, Mined, and Unmined) were compared using one-way analysis of variance (ANOVA). Assumptions for normality and equal variance were assessed using the Shapiro-Wilk Test for normality and Brown and Forsythe's Test for homogeneity of variance. If necessary, transformations were applied to the data to achieve normality and/or stabilize the variance. Significant differences ($p < 0.05$) among EIS classes were followed by the Least Square (LS) Means procedure using Dunnett's adjustment for multiple comparisons to test whether the Filled, Filled/Residence, and Mined EIS classes were significantly different ($p < 0.01$) from the Unmined EIS class. Additive sites from two watersheds were analyzed to evaluate the second objective. Trends in biological condition along the mainstem of Twentymile Creek and Twelvepole Creek were examined using Pearson correlations and regression analysis. Pearson correlations were also used to investigate correlations between biological endpoints and water chemistry parameters. Box plots were generated to display the data across EIS classes and scatter plots were created to show relationships between biological endpoints and chemistry parameters.

3.3.1. Summary of Fish Analysis





Endpoints for the fish analysis were the site
averages for the Mid-Atlantic IBI and the site averages for the nine individual metrics that comprise the IBI (Table 1-2). Site averages were used in the analysis since the number of samples taken at a site was inconsistent across sites. Some study sites had been sampled only once, and there were also sites in the database that had been sampled on two or three separate occasions. Mean IBI and component metric values were calculated for all sites sampled multiple times. The mean values were used in all subsequent analyses. Figure 3-1 shows that there was no consistent difference between seasons or years, although there was scatter among observations at some sites. Log-transformed site (geometric) mean chemical concentrations were used as the endpoints for the chemistry analysis.

Figure 3-1. Scatter plots showing IBI scores of sites sampled multiple times. The left plot shows autumn samples versus spring samples and the right plot shows spring Year 2 samples versus spring Year 1 samples.

3.3.2. Summary of Macroinvertebrate Analysis

Endpoints for the macroinvertebrate analysis were the WV SCI and its component metrics (Total taxa richness, Ephemeroptera-Plecoptera-Trichoptera [EPT] taxa richness, Hilsenhoff Biotic Index [HBI], % dominant 2 taxa, % EPT abundance, and % Chironomidae abundance). Richness metrics and the WV SCI were rarefacted to 100 organisms to adjust for sampling effort. Comparisons among EIS classes were made for each season (Spring 1999 [April to June], Autumn 1999 [October to December], Winter 2000 [January to March], Spring 2000, Autumn 2000, and Winter 2001). Data for Summer 1999 (July to September) were not compared because of a lack of samples (n= 2) for the Unmined EIS class (i.e., the relative control). Furthermore, in some seasons there were insufficient samples (n < 3) for the Mined and Filled/Residence classes. The WVSCI scores were correlated against key water quality parameters using mean values for each site. Only water chemistry data that were collected at or close to the time of benthos sample collection were used in this analysis.

Habitat data was not evaluated due to the fact that it was not collected consistently and in many cases was collected only once at a site.

4. RESULTS

4.1. Fish Results

4.1.1. IBI Calculation and Calibration

Generally, larger watersheds tend to be more diverse than smaller watersheds (i.e., Karr et al. 1986, Yoder and Rankin 1995). This was found to be true in the MTM/VF study where the smallest headwater streams often had either no fish present or only one or two species present and the large streams had 15 to 27 fish species present (Figure 4-1). To ensure that differences among fish communities were due to differences in stream health and not from the natural effect of watershed size, the three richness metrics (i.e., Native Intolerant Taxa, Native Cyprinidae Taxa and Native Benthic Invertivores) from the Mid-Atlantic Highlands IBI (Section 1.5) were standardized to a 100-km^2 watershed. If the calibration was correct, then there should have been no residual relationship between catchment area and IBI scores. The resultant IBI scores were plotted against catchment area (Figure 4-2) which showed that there was no relationship.

The Mid-Atlantic IBI was not calculated if the catchment area was less than 2.0 km^2. If fewer than ten fish were captured in a sample, then the IBI was set to zero (McCormick et al. 2001). This occurred in six samples. All six of these samples were in relatively small catchments (i.e., 2.0 to 5.0 km^2), where small samples are likely (Figure 4-2). Because small samples may be due to natural factors, these samples were excluded from subsequent analysis..

4.1.2. IBI Scores in EIS Classes

The distributions of IBI scores in each of the EIS classes are shown in Figure 4-3. Distributions of the nine component metrics of the IBI are shown in Appendix B. For comparison, the regional reference sites sampled by the PSU in Big Ugly Creek were also plotted. Figure 4-3 shows that the Filled and Mined classes have lower overall IBI scores than the other EIS classes. The Filled/Residential class had higher IBI scores than any other class. The Filled/Residential class and the Unmined class had median scores that were similar to the regional reference sites. Figure 4-3 shows that more than 50% of the Filled and Mined sites scored “poor” according to the ratings developed by McCormick et al. (2001). Unmined and regional reference sites were primarily in the “fair” range and Filled/Residential sites were mostly in the “good” ranges.

Figure 4-1. Number of fish species captured versus stream catchment area. Symbols identify sampling organizations: PSU=Penn State; Pen = Pen Coal (REIC); Fola = Fola Coal (Potesta); Mingo = Mingo-Logan Coal (BMI).

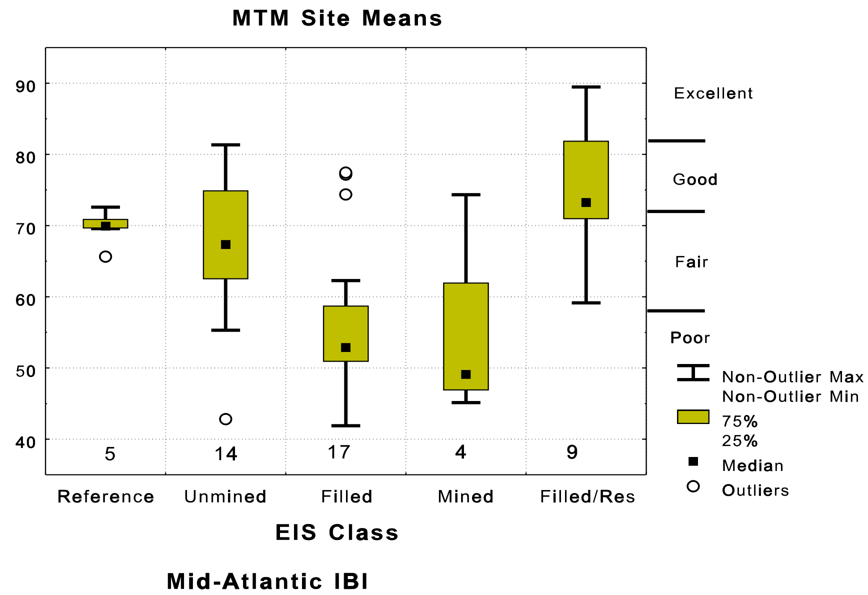


Figure 4-2. Calculated Fish IBI and watershed catchment area, all MTM fish samples from sites with catchment > 2km^2. Symbols identify sampling organizations: PSU=Penn State; Pen = Pen Coal (REIC); Fola = Fola Coal (Potesta); Mingo = Mingo-Logan Coal (BMI).

Figure 4-3. A Box-and-Whisker plot of the mean IBI scores from sampling sites in five EIS classes. Catchments less than 2 km^2 and samples with less than ten fish were excluded. Numbers below boxes indicate sample size. Reference sites were the five regional reference sites in Big Ugly Creek, outside of study area. All other sites were in the MTM study area. Assessment categories (McCormick et al.2001) are shown on right side.

A one-way ANOVA was used to test for differences among EIS classes and the LS Means procedure with Dunnett's adjustment was used to compare each class to the Unmined class. The ANOVA showed that differences among the EIS classes were statistically significant (Table 4-1) and the LS Means test showed that the IBI scores from the Filled sites were significantly lower than the IBI scores from the Unmined sites (Table 4-2). The Filled/ Residential class had higher IBI scores than the Unmined sites (Figure 4-3). The IBI scores from Mined sites were lower than the IBI scores from Unmined sites. However, the difference was only marginally significant. This is most likely due to the small sample of Mined sites (n=4). Diagnostics on the IBI analysis indicated that variance was homogeneous and residuals of the model were normally distributed (Figure 4-4 and Appendix B).

The individual metrics that comprise the IBI are not uniform in their response to stressors (McCormick et al. 2001). While some metrics may respond to habitat degradation, other metrics may respond to organic pollution or toxic chemical contamination. Of the nine metrics in the IBI, two (i.e., the number of cyprinid species and the number of benthic invertivore species) were significantly different among the EIS classes. (Appendix B). On average, Filled sites were missing one species of each of these two groups compared to Unmined sites. The third taxa richness metric, Number of Intolerant Species, was not different between Filled and Unmined sites (Appendix B). One additional metric, Percent Tolerant Individuals, showed increased degradation in Filled and Mined sites compared to Unmined sites, on average, but the difference was not statistically significant (Appendix B). Four metrics, Percent Cottidae, Percent Gravel Spawners, Percent Alien Fish and Percent Large Omnivores, were dominated by zero values (Appendix B). Because of the zero values and the resultant non-normal distribution, parametric hypothesis tests would be problematic.

It was concluded from this analysis that the primary causes of reduced IBI values in Filled sites were reductions in the number of minnow species and the number of benthic invertivore species. These two groups of fish are dominant in healthy Appalachian streams. Secondary causes of the reduction of IBI scores in Filled sites are decreased numbers of intolerant taxa, and increased percentages of fish tolerant to pollution. Although Filled sites had IBI scores that were significantly lower than Unmined sites (Table 4-3), several Filled and Mined sites had relatively high IBI scores, similar to regional reference and Unmined sites. In addition, the Filled/Residential sites had higher overall IBI scores. Field crews had observed that there were very few or no residences in the small watersheds of the headwater stream areas. This suggests that the sites where fills and residences were co-located occurred most frequently in larger watersheds and that watershed size may buffer the effects of fills and mines. This possibility was examined and it was found that Filled, Mined, and Filled/Residential sites in watersheds with areas greater than 10 km^2 had fair to good IBI scores. However, Filled and Mined sites in watersheds with areas less than 10 km^2 often had poor IBI scores (Figure 4-5A). Of the 14 sites in watersheds with areas greater than 10 km^2, four were rated fair and ten were rated good or better (Figure 4-5A). Of the 17 sites in watersheds with areas less than 10 km^2, only three rated fair and 14 rated poor (Figure 4-5). In contrast, the control and reference sites showed no overall association with catchment area (Figure 4-5B). The smallest sites (i.e., watershed areas < 3.0 km^2) were highly variable, with three of the five smallest sites scoring poor.

Figure 4-4. Normal probability plot of IBI scores from EIS classes.

Table 4-1. The ANOVA for IBI scores among EIS classes (Unmined, Filled, Mined, and Filled/Residential).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2335.56	778.52	6.70	0.0009
Error	40	4651.31	116.28		
Corrected Total	43	6986.87			

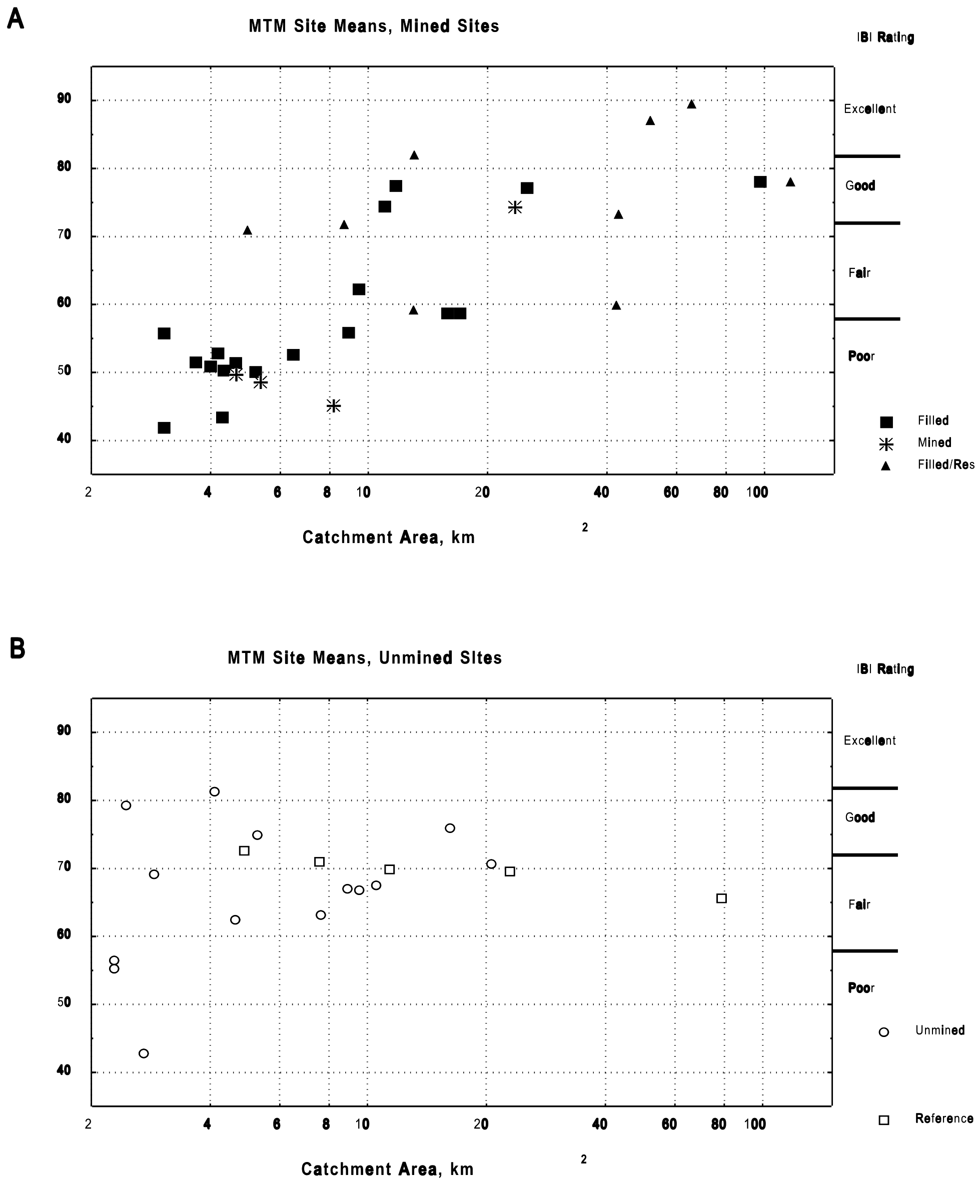
R-Square	Coefficient of Variance	Root MSE	Index Mean
0.334	17.022	10.783	63.350

Table 4-2. Dunnett's test comparing IBI values of EIS classes to the Unmined class, with the alternative hypothesis that IBI < Unmined IBI (one-tailed test).

EIS Class	N	Mean	Standard Deviation	Dunnett's P-Value
Filled	**17**	**56.8**	**10.6**	**0.0212**
Filled/Residential	**9**	**74.6**	**10.7**	**0.9975**
Mined	**4**	**54.4**	**13.4**	**0.0685**
Unmined	**14**	**66.7**	**10.3**	**--**

The effect of fills was statistically stronger in watersheds with areas less than 10 km^2 (Table 4-3). Filled sites had an average of one fewer Cyprinidae species, 1.6 fewer benthic invertivore species, 20% more tolerant individuals, and a mean IBI score that is 14 points lower than Unmined sites (Table 4-3). In addition, Intolerant Taxa, % Cottidae and % Gravel Spawners decreased slightly in the filled sites and the % Macro Omnivores increased slightly (Table 4-3). There were too few small Mined sites (n=3) and too few small Filled/Residential sites (n=2) to test against the Unmined sites within the small size category.

There is no definitive test to determine whether the high IBI scores of the Filled/Residential sites in this data set are due solely to large catchment areas or if there may be other contributing factors. The Filled/Residential class is consistent with the relationship observed in the Filled sites, that large catchments are less susceptible to the effects of fills and mines. A definitive test could be conducted if data were collected from several small Filled/Residential catchments.



Mid-Atlantic IBI   Mid-Atlantic IBI

Figure 4-5. The IBI scores for different site classes, by watershed area. Assessment categories (McCormick et al.2001) are shown on right. A) Filled, Mined, and Filled/ Residential sites. B) Unmined and Reference (Big Ugly Creek) sites.

Table 4-3. The results of t-tests of site mean metric values and the IBI in Unmined and Filled sites in watersheds with areas less than 10 km^2 (N = 11 Unmined, N = 12

Filled).

	Mean Unmined	Mean Filled	t-value	p
Cyprinidae Taxa	5.41	4.37	2.93	0.008
Intolerant Taxa	1.03	0.85	1.23	0.232
Benthic Invertivore Taxa	5.80	4.22	3.73	0.001
% Exotic	0.3	0.9	-0.65	0.524
% Cottidae	3.8	0.4	1.42	0.172
% Gravel Spawners	17.2	7.0	0.999	0.329
% Piscivore/Invertivores	34.8	38.8	-0.34	0.739
% Tolerant	71.8	93.8	-2.60	0.0167
% Macro Omnivore	1.4	4.8	-1.54	0.139
IBI	65.4	51.5	3.80	0.001

4.1.3. Additive Analysis

Sites on the mainstem of Twentymile Creek and all mining-affected sites in the Twelvepole Creek watershed have been identified as Additive sites, and were not included in the analysis of the EIS classes reported above. Instead, these sites were considered to be subject to multiple and possibly cumulative sources (i.e., VFs, historic mining, non-point runoff, untreated domestic sewage, non-permitted discharges).

The Twelvepole Creek watershed, in particular, has mixed land uses and has several mining techniques in use. The stream valleys are often populated with residences and livestock. Mining in the Twelvepole watershed includes deep mining, contour mining, and mountaintop removal/VF. In contrast, there is little or no residential land use in the Twentymile Creek watershed and all human activities in the Twentymile Creek are related to mining (i.e., logging and grubbing).

The IBI scores of sites in three streams (i.e., Kiah Creek, Trough Fork, and Twelvepole Creek) in the Twelvepole Creek Watershed are shown in Figure 4-6. Most of the sites are scored in the “fair” range, although a few observations extend into the “good” and “poor” ranges (Figure 4-6). There is no apparent pattern in these scores and there are no trends from upstream to downstream in either of the larger streams (i.e., Kiah Creek and Twelvepole Creek).

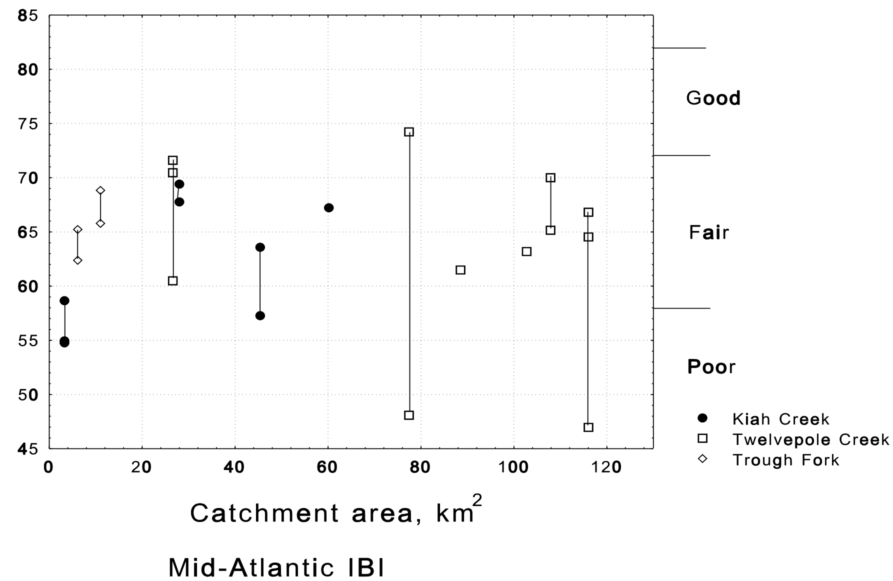
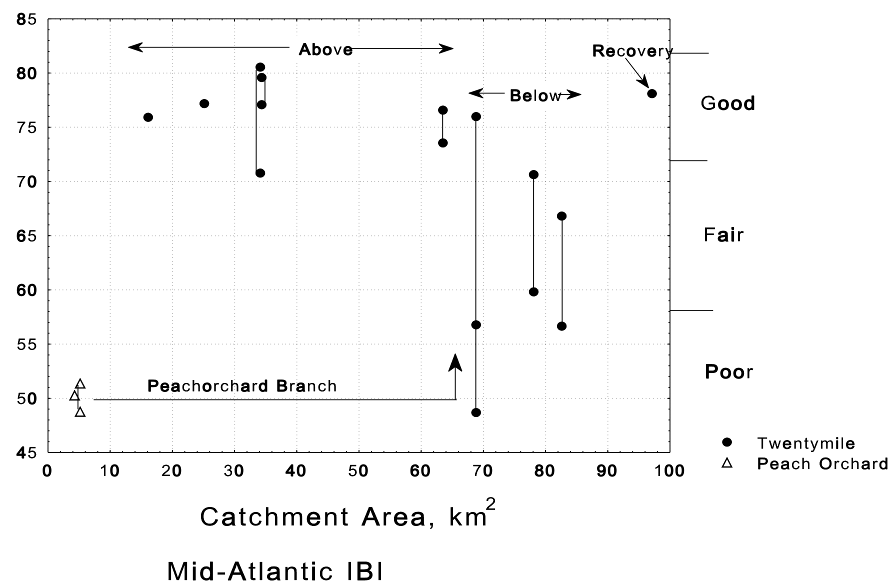


Figure 4-6. The IBI scores from the additive sites in the Twelvepole Creek Watershed. Multiple observations from single sites are connected with a vertical line.

Figure 4-7. IBI scores from additive sites and Peachorchard Branch in the Twentymile Creek Watershed. Multiple observations from single sites are connected with a vertical line.



Overall, the IBI scores in the Twentymile Creek watershed were higher than those in

Twelvepole Creek. There was a trend, from upstream to downstream, among the scores from the Twentymile Creek Watershed (Figure 4-7). Above Peachorchard Branch, which has a catchment area smaller than 68 km^2, sites on the mainstem of Twentymile Creek were uniformly in the "good" range of IBI scores, with moderate variability. Below the confluence of Peachorchard Branch, IBI scores decrease overall and are more variable (Figure 4-7). Farther downstream (i.e., Site PSU.54), the IBI score was higher (i.e., 78), indicating potential recovery from the stressors in the lower portion of the stream. With a range of 48 to 52, Peachorchard Branch had among the lowest IBI scores in the Twentymile Creek Watershed.

4.1.4. Associations With Potential Causal Factors

The correlations between IBI scores and water quality parameters that are potential stressors (i.e., DO, pH, nutrients, TDS, TSS, salts, and metal concentrations) were examined. For the correlation analysis, site mean IBI scores and log-transformed site (geometric) mean chemical concentrations were used. The correlation analysis was restricted to sites in watersheds with areas smaller than 10.0 km^2. The IBI scores decreased with the increased concentrations of several water quality parameters, and decreased significantly with increased zinc and sodium (Table 4-4). However, these correlations do not imply causal relationships between water quality parameters and fish community condition. Other substances or processes associated with mining activity (i.e., erosion, sedimentation), but not measured, could also be proximal causal factors.

Table 4-4. Pearson correlations among the site means of selected water quality measurements and IBI scores, including all sites in watersheds with areas smaller than 10 km^2.

	Log Cr	Log Mg	Log Ni	Log (NO_3+	Log Na	Log SO_4	Log TDS	Log Zn
Log Mg	0.11							
Log Ni	-0.08	0.53						
Log (NO_3+NO_2)	0.40	0.65	0.37					
Log Na	0.16	0.40	-0.08	0.65				
Log SO_4	0.17	0.96	0.43	0.76	0.58			
Log TDS	0.27	0.42	-0.35	0.79	0.90	0.65		
Log Zn	0.50	0.34	0.12	0.47	0.34	0.38	0.42	
IBI	-0.35	-0.42	-0.33	-0.42	-0.60	-0.51	-0.47	-0.54

4.2. Macroinvertebrate Results

4.2.1. Analysis of Differences in EIS Classes

For each season, analyses were conducted to determine if there were any differences among the EIS classes. Only Unmined, Filled, Mined and Filled/Residential sites were used for these analyses. Analysis endpoints were the WVSCI and it's component metrics.

4.2.1.1. Spring 1999

This comparison only used U.S. EPA Region 3 data for each watershed. All of the tested metrics were significantly different among EIS classes using ANOVA, and each met the assumptions for normality and equal variance (Table 4-5). The WVSCI and the taxa richness metrics differed significantly between Unmined sites and both Filled and Filled/Residential sites in the LS Means test. Percent EPT Abundance was also significantly different between Unmined sites and Filled/Residential sites. Box plots for each metric comparison are in Appendix C.

4.2.1.2. Autumn 1999

This comparison used data collected by both the U.S. EPA Region 3 and the private organizations for each watershed. Only the WVSCI, Percent EPT and Percent Chironomidae Abundance were significantly different among EIS classes (Table 4-6). However, the Unmined sites were not significantly different from the other classes for these metrics. Box plots for each metric comparison are in Appendix C. Drought conditions occurred during this season, and streams were further impacted by a severe drought during the preceding summer.

Table 4-5. Results from ANOVA for benthic macroinvertebrates in spring 1999. Uses Unmined sites as a relative control for LS Means test. Total n = 34; Unmined n = 9, Mined n = 4, Filled n = 15, Filled/Residential n = 6.

Metric	p-value	Normality?	Equal Variance?	LS Means
WVSCI (Rarefied to 100 Organisms)	<0.0001	Yes	Yes	Filled and Filled/Residential
Total Taxa (Rarefied to 100 Organisms)	0.0001	Yes	Yes	Filled and Filled/Residential
EPT Taxa (Rarefied to 100 Organisms)	<0.0001	Yes	Yes	Filled and Filled/Residential
HBI	0.0017	Yes	Yes	
Percent Dominant Two Taxa (Arcsine Transformed)	0.0010	Yes	Yes	
Percent EPT Abundance (Arcsine Transformed)	0.0010	Yes	Yes	Filled/Residential
Percent Chironomidae Abundance (Arcsine Transformed)	0.0326	Yes	Yes	

Table 4-6. Results from ANOVA for benthic macroinvertebrates in autumn 1999. Uses Unmined sites as a relative control for LS Means test. Total n = 35, Unmined n = 6, Filled n = 23, Filled/Residence n = 6.

Metric	p-value	Normality ?	Equal Variance?	LS Means
WVSCI (Rarefied to 100 Organisms)	0.0454	Yes	Yes	
Total Taxa (Rarefied to 100 Organisms)	0.3744	Yes	Yes	
EPT Taxa (Rarefied to 100 Organisms)	0.2401	Yes	Yes	
HBI	0.1299	Yes	Yes	
Percent Dominant Two Taxa (Arcsine Transformed)	0.2672	Yes	Yes	
Percent EPT Abundance (Arcsine Transformed)	0.0178	Yes	Yes	

Percent Chironomidae Abundance (Arcsine Transformed)	**0.0253**	**Yes**	**Yes**

4.2.1.3. Winter 2000

This comparison used data collected by both the U.S. EPA Region 3 and the private organizations for each watershed. All of the tested metrics were significantly different among EIS classes, and each met the assumptions for normality (Table 4-7). The WVSCI and the HBI failed the test for equal variance. The WVSCI and the Total Taxa metrics differed significantly between Unmined sites and both Filled and Filled/Residential sites in the LS Means test. Percent EPT abundance was also significantly different between Unmined sites and Filled/Residential sites. Box plots for each metric comparison are in Appendix C.

4.2.1.4. Spring 2000

This comparison used only the data collected by the U.S. EPA Region 3 for each watershed. All of the tested metrics were significantly different among EIS classes, and each met the assumptions for normality (Table 4-8). The WVSCI, EPT Taxa, HBI, and Percent EPT Abundance failed the test for equal variance. The WVSCI and the taxa richness metrics differed significantly between Unmined sites and both Filled and Filled/Residence sites in the LS Means test. Percent EPT abundance in the Unmined sites was also significantly different than in Filled/Residence sites. Box plots for each metric comparison are in Appendix C.

4.2.1.5. Autumn 2000

This comparison used only the data collected by the private organizations for the Twentymile Creek watershed. No metrics were significantly different among EIS classes (Table 4-9). Box plots for each metric comparison are in Appendix C.

4.2.1.6. Winter 2001

This comparison used only the data collected by the private organizations for the Twentymile Creek watershed. The WVSCI, Total Taxa, EPT Taxa, and Percent Dominant 2 Taxa were significantly different among EIS classes (Table 4-10). The Unmined sites were significantly different than the Filled classes for the WVSCI and EPT Taxa, although both metrics failed the equal variance test. Box plots for each metric comparison are in Appendix C.

Table 4-7. Results from ANOVA for benthic macroinvertebrates in winter 2000. Uses Unmined sites as a relative control for LS Means test. Total n = 53, Unmined n = 18, Mined n = 4, Filled n =25, Filled/Residential n = 6.

Metric	p-value	Normality ?	Equal Variance?	LS Means
WVSCI (Rarefied to 100 Organisms)	<0.0001	Yes	No	Filled and Filled/Residential
Total Taxa (Rarefied to 100 Organisms)	<0.0001	Yes	Yes	Filled and Filled/Residential
EPT Taxa (Rarefied to 100 Organisms)	<0.0001	Yes	Yes	Filled and Filled/Residential
HBI	<0.0001	Yes	No	
Percent Dominant Two Taxa (Arcsine Transformed)	<0.0001	Yes	Yes	
Percent EPT Abundance (Arcsine Transformed)	<0.0001	Yes	Yes	Filled and Filled/Residential
Percent Chironomidae Abundance (Arcsine Transformed)	<0.0001	Yes	Yes	

Table 4-8. Results from ANOVA for benthic macroinvertebrates in spring 2000. Uses Unmined sites as a relative control for LS Means test. Total n = 35, Unmined n = 10, Mined n = 5, Filled n = 15, Filled/Residence n = 5.

Metric	p-value	Normality ?	Equal Variance?	LS Means
WVSCI (Rarefied to 100 Organisms)	0.0001	Yes	No	Filled and Filled/Residential
Total Taxa (Rarefied to 100 Organisms)	0.0004	Yes	Yes	Filled and Filled/Residential
EPT Taxa (Rarefied to 100 Organisms)	<0.0001	Yes	No	Filled and Filled/Residential

HBI	0.0002	Yes	No	
Percent Dominant Two Taxa (Arcsine Transformed)	<0.0001	Yes	Yes	
Percent EPT Abundance (Arcsine Transformed)	0.0027	Yes	No	Filled/Residential
Percent Chironomidae Abundance (Arcsine Transformed)	0.0020	Yes	Yes	

Table 4-9. Results from ANOVA for benthic macroinvertebrates in autumn 2000. Uses Unmined sites as a relative control for LS Means test. Total n = 15; Unmined n = 5, Filled n = 10.

Metric	p-value	Normality?	Equal Variance?	LS Means
WVSCI (Rarefied to 100 Organisms)	0.1945	Yes	Yes	
Total Taxa (Rarefied to 100 Organisms)	0.4744	Yes	Yes	
EPT Taxa (Rarefied to 100 Organisms)	0.1897	Yes	Yes	
HBI	0.7243	Yes	Yes	
Percent Dominant Two Taxa (Arcsine Transformed)	0.0846	Yes	Yes	
Percent EPT Abundance (Arcsine Transformed)	0.3200	Yes	Yes	
Percent Chironomidae Abundance (Arcsine Transformed)	0.4417	Yes	Yes	

Table 4-10. Results from ANOVA for benthic macroinvertebrates in winter 2001. Uses Unmined sites as a relative control for LS Means test. Total n = 16, Unmined n = 6, Filled n = 10.

Metric	p-value	Normality?	Equal Variance?	LS Means
WVSCI (Rarefied to 100 Organisms)	0.0110	Yes	No	Filled

Total Taxa (Rarefied to 100 Organisms)	**0.0275**	**Yes**	**Yes**	
EPT Taxa (Rarefied to 100 Organisms)	**0.0074**	**Yes**	**No**	**Filled**
HBI	**0.4874**	**Yes**	**Yes**	
Percent Dominant Two Taxa (Arcsine Transformed)	**0.0012**	**Yes**	**Yes**	
Percent EPT Abundance (Arcsine Transformed)	**0.3449**	**Yes**	**Yes**	
Percent Chironomidae Abundance (Arcsine Transformed)	**0.1180**	**Yes**	**Yes**	

4.2.2. Evaluation of Twentymile Creek

Box plots were used to compare benthic macroinvertebrate metrics in the major watersheds during spring 1999, autumn 1999, winter 2000, and spring 2000. Only data from Twentymile Creek was available for autumn 2000 and winter 2001 and it was necessary to examine whether the EIS data collected from the Twentymile Creek Watershed was similar to the EIS data collected from the other four watersheds. Clear Fork could not be used in this watershed analysis, since data for Clear Fork were limited (i.e., there were no Unmined sites and only one Filled site).

No consistent differences in the benthic metrics between the Unmined sites and among watersheds were observed (Appendix C). In contrast, there were consistent differences in the benthic metrics between Filled sites and among watersheds in each season except autumn 1999. Total Taxa, EPT Taxa, Percent EPT Abundance, and the WVSCI were consistently better in Twentymile Creek and Island Creek watersheds than in the Mud River and Spruce Fork watersheds (Appendix C).

4.2.3. Macroinvertebrate and Water Chemistry Associations

The WVSCI scores were correlated against key water quality parameters using mean values for each site. Only water chemistry data that were collected at or close to the time of benthos sample collection were used in this analysis.

The strongest associations were negative correlations between the WVSCI and measures of individual and combined ions (Table 4-11, Appendix D). The WVSCI was also negatively correlated with the metals Beryllium, Selenium, and Zinc.

4.2.4. The Effect of Catchment Area on the WVSCI

The WVSCI and its component metrics had not been evaluated for potential effects related to stream size because of a lack of catchment area data during the original index development. The WVSCI and its component metric scores calculated from the MTM/VF data were plotted against catchment area. A Pearson correlation analysis was also run on these data to investigate whether stream size influenced these scores for the MTM/VF EIS analysis. This analysis was only conducted for the sites in the Unmined EIS class in order to limit any confounding variation due to anthropogenic sources.

There were 20 Unmined sites available for this analysis. However, one site was dropped because catchment area data for that site was unavailable. Because sample size varied greatly

Table 4-11. Results from Pearson correlation analyses between the WVSCI rarefied to 100 organisms and key water quality parameters.

Parameter	n	R	P-value
Alkalinity	53	-0.660	<0.001
Total Aluminum	47	-0.208	0.161
Total Beryllium	52	-0.298	0.032
Total Calcium	53	-0.624	<0.001
Total Chromium	53	-0.043	0.761
Conductivity	53	-0.690	<0.001
Total Copper	53	-0.238	0.086
Hardness	23	-0.650	0.001
Total Iron	49	-0.189	0.193
Total Magnesium	53	-0.569	<0.001
Total Manganese	49	-0.241	0.095
Total Nickel	53	-0.166	0.235
Nitrate/Nitrite	21	-0.362	0.106
DO	60	0.031	0.815

Total Phosphorus	53	-0.165	0.237
Total Potassium	53	-0.527	<0.001
Total Selenium	51	-0.476	<0.001
Total Sodium	53	-0.572	<0.001
Sulfate	53	-0.598	<0.001
Total Dissolved Solids	53	-0.371	0.006
Total Zinc	53	-0.343	0.012

among seasons and was very low in some seasons (i.e., n = 5 or 6), the mean score for each site was used in the analyses.

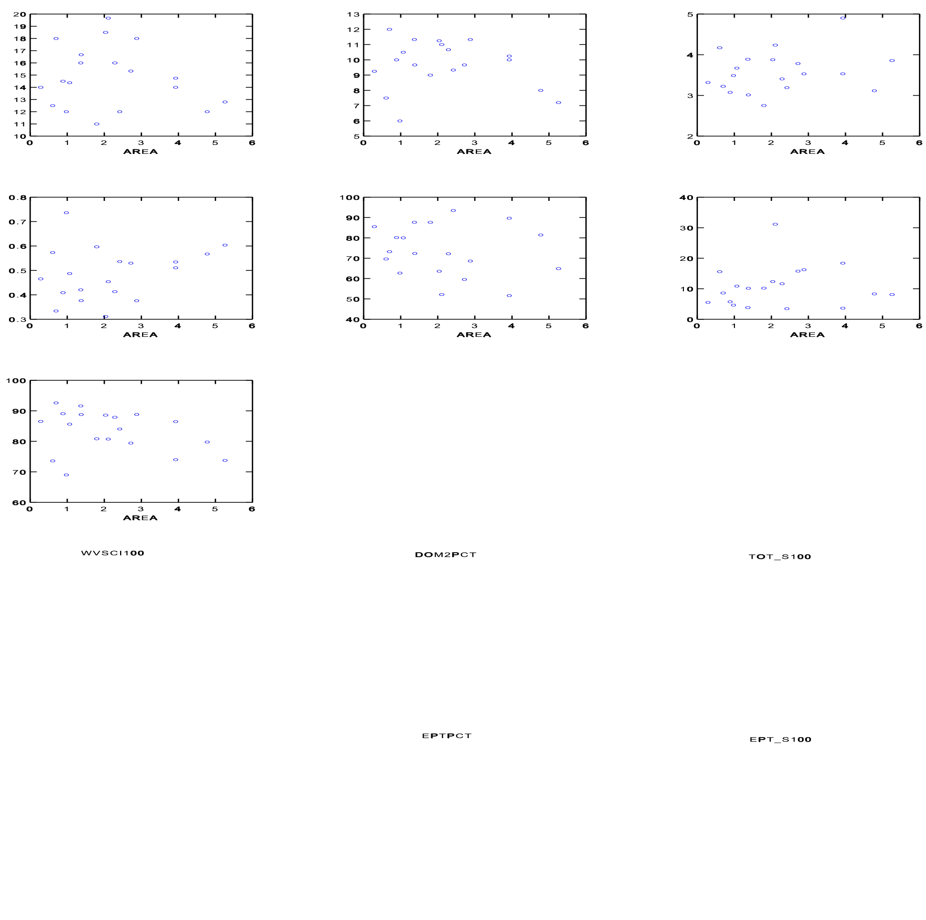
Neither correlation analyses (Table 4-12) nor scatter plots (Figure 4-8) showed an effect of catchment area on the WVSCI and its metric scores. Analyses with arcsin transformed proportion metrics (i.e., Percent Dominant Two Taxa, Percent EPT Taxa, and Percent Chironomid Taxa) also showed no relationship to catchment area ® = 0.269, -0.144, and 0.090, respectively)

Although no relationship was found, these analyses were limited by the relatively low sample sizes available, and the limited range in catchment area (0.29 – 5.26 km^2) data for Unmined sites. Additional data for larger and relatively undisturbed stream sites within the MTM/VF footprint is necessary to examine stream size effects for the three larger (i.e., area > 40 km^2) Filled/Residence sites. It is unclear whether such sites exist in this area.

Table 4-12. Pearson correlation values and p-values for means of metric scores at Unmined sites (n = 19) versus catchment area.

Metric	R	p-value
Tot_S100	-0.157	0.520
EPT_S100	-0.165	0.501
HBI	0.228	0.348
Dom2Pct	0.255	0.293
EPTPct	-0.168	0.493
ChirPct	0.087	0.724
WVSCI100	-0.312	0.194

Figure 4-8. The WVSCI and its metric scores versus catchment area in Unmined streams.



4.2.5. Additive Analysis

Multiple sites on the mainstem of Twentymile Creek were identified as Additive sites and were included in an analysis to evaluate impacts of increased mining activities in the watershed across seasons and from upstream to downstream of the Twentymile Creek. Cumulative river kilometer was calculated for each site along Twentymile Creek as the distance from the uppermost site, Rader 8. The total distance upstream to downstream was approximately 17 kilometers. Sites were sampled during four seasons, Autumn 1999 (n = 19), Winter 2000 (n = 23), Autumn 2000 (n = 24) and Winter 2001 (n = 26). Pearson correlations between cumulative river kilometer and the WVSCI and it's component metrics were calculated for each season (Table 4-13). The number of metrics that showed significant correlations with distance along the mainstem increased across seasons. The WVSCI was significantly correlated with cumulative river kilometer in Winter 2000, Autumn 2000 and Winter 2001. In Winter 2001, four of the six individual metrics also showed significant correlations with distance along the mainstem of Twentymile Creek. A linear regression of the WVSCI with cumulative river kilometer indicated that the WVSCI decreased approximately one point upstream to downstream for every river kilometer (Table 4-14).

Table 4-13. Pearson correlation values and p-values for metric scores at Additive sites on Twentymile Creek versus cumulative river kilometer by season.

Metric	Autumn 1999	Winter 2000	Autumn 2000	Winter 2001
Tot_S100	-0.582 (0.009)	0.051 (0.8169) (pvalue=0.817)	-0.670 (<.001)	-0.462 (0.018)
EPT_S100	-0.480 (0.038)	-0.230 (0.196)	-0.688 (<.001)	-0.593 (0.002)
HBI	-0.210 (0.387)	-0.227 (0.296)	-0.228 (0.284)	0.410 (0.037)
Dom2Pct	0.360 (0.130)	0.521 (0.011)	0.626 (0.001)	0.545 (0.004)
EPTPct	0.018 (0.940)	-0.004 (0.986)	0.145 (0.499)	-0.235 (0.248)
ChirPct	-0.075 (0.759)	-0.377 (0.076)	-0.048 (0.824)	0.091 (0.658)
WVSCI100	-0.353 (0.138)	0.762 (<.001)	-0.627 (0.001)	-0.608 (0.001)

Table 4-14. The Regression for WVSCI versus Cumulative River Mile for Additive Sites in Twentymile Creek Winter 2001.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	658.99	658.99	14.05	0.0010
Error	24	1125.55	46.90		
Corrected Total	25	1784.54			

R-Square	Coefficient of Variance	Root MSE	WVSCI Mean
0.369	8.27	6.848	82.80

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	92.66	2.95	31.38	<.0001
Cumulative River Km	-1.14	0.30	-3.75	0.001

5. DISCUSSION AND CONCLUSIONS

5.1. Fish Discussion and Conclusions

From the analysis of the fish data among the EIS classes, it was determined that IBI scores were significantly reduced in streams below VFs, compared to unmined streams, by an average of 10 points, indicating that fish communities were degraded below VFs. The IBI scores were similarly reduced in streams receiving drainage from historic mining or contour mining, compared to unmined streams. Nearly all filled and mined sites with catchment areas smaller than 10.0 km^2 had “poor” IBI scores, whereas filled and mined sites with catchment areas larger than 10.0 km^2 had “fair” or “good” IBI scores. In the small streams, IBI scores from Filled sites were an average of 14 points lower than the IBI scores from Unmined sites. Most Filled/Residential sites were in larger watersheds (i.e., areas > 10.0 km^2), and Filled/Residential sites had “fair” or “good” IBI scores.

From the additive analysis, it was determined that the Twelvepole Creek Watershed, in which the land use was mixed residential and mining, had “fair” IBI scores in most samples, and there are no apparent additive effects of the land uses in the downstream reaches of the watershed. Also, Twentymile Creek, which has only mining-related land uses, has “Good” IBI scores upstream of the confluence with Peachorchard Creek, and “Fair” and “Poor” scores for several miles downstream of the confluence with Peachorchard Creek tributary. Finally, Peachorchard Creek has “Poor” IBI scores, and may contribute contaminants or sediments to Twentymile Creek, causing degradation of the Twentymile IBI scores downstream of Peachorchard Creek.

5.2. Macroinvertebrate Discussion and Conclusions

The results of the macroinvertebrate analyses showed significant differences among EIS classes for the WVSCI and some of its component metrics in all seasons except autumn 2000. Differences in the WVSCI were primarily due to lower Total Taxa, especially for mayflies, stoneflies, and caddisflies, in the Filled and Filled/Residential EIS classes.

Sites in the Filled/Residential EIS class usually scored the worst of all EIS classes across all seasons (Appendix C). It was not determined why the Filled/Residential class scored worse than the Filled class alone. U.S. EPA (2001 Draft) found the highest concentrations of Na in the Filled/Residential EIS class, which may have negatively impacted these sites compared to those in the Filled class.

When the results for Filled and Unmined sites alone were examined, significant differences were observed in all seasons except autumn 1999 and autumn 2000. This can be seen in the plots of the WVSCI, Total Taxa, and EPT Taxa versus season (Figures 5-1, 5-2a and 5-2b). The lack of differences between Unmined and Filled sites in autumn 1999 was due to a decrease in Total Taxa and EPT Taxa in Unmined sites relative to a lack of change in Filled sites. These declines in taxa richness metrics in Unmined sites was likely a result of the drought conditions of the summer 1999, which caused more Unmined sites to go dry or experience severe declines in flow relative to Filled sites (Green et al., 2000). Wiley et al. (2001) also found that Filled sites have daily flows that are greater than those in Unmined sites during periods of low discharge. Despite the relatively drier conditions in Unmined sites during autumn 1999, WVSCI scores and EPT Taxa richness increased in later seasons to levels seen in the spring 1999 season whereas values for Filled sites stayed relatively low.

The lack of statistical differences between Unmined and Filled classes in the autumn 2000 appears to be due to a decline of Total Taxa richness in Unmined sites coupled with an increase in Total Taxa richness in Filled sites (Figures 5-1, 5-2 and 5-3). Filled sites had higher variability in WVSCI scores and metric values than did Unmined sites during the autumn 2000, which also contributed to the lack of significant differences. It is important to note that this comparison only uses data from the Twentymile Creek Watershed. Hence, the lack of differences in metrics during the autumn 2000 between Unmined and Filled sites is only relevant for the Twentymile Creek watershed, and not the entire MTM/VF study area examined in the preceding seasons. Similarly, data for winter 2001 is only representative of the Twentymile Creek watershed, but it is noteworthy that these data did show that Unmined and Filled sites were significantly different. It was also found that Filled sites in the Twentymile Creek Watershed scored better than filled sites in the Mud River and Spruce Fork Watersheds in all seasons except for autumn 1999. These differences among watersheds indicate biological conditions in Filled sites of the Twentymile Creek watershed are not representative of the range of conditions in the entire MTM/VF study area. As a result, comparisons among EIS classes during autumn 2000 and winter 2001 should not be considered typical for the entire MTM/VF study area.

Statistical differences between the Unmined and Filled EIS classes corresponded to ecological differences between classes based on mean WVSCI scores. Unmined sites scored in the Very Good condition category in all seasons except autumn 1999 when the condition was scored as Good. The conditions at Filled sites ranged from Fair to Good (Figure 5-1). However, Filled sites that scored Good on average only represented conditions in the Twentymile Creek watershed in two seasons (i.e., autumn 2000 and winter 2001), and these sites are not representative of the entire MTM/VF study area. On average Filled sites were in worse ecological condition than were Unmined sites.

Figure 5-1. Mean WVSCI scores in the Unmined and Filled EIS classes versus sampling season. Error bars are 1 SE. Data for autumn 2000 and winter 2001 only used private organization data for the Twentymile Creek Watershed. The condition categories are based on Green et al. (2000 Draft).

A

B

Figure 5-2. (A) Mean Total Taxa richness in the Unmined and Filled EIS classes versus sampling season. (B) Mean EPT Taxa richness in the Unmined and Filled EIS classes versus sampling season. Error bars are 1 SE. Data for autumn 2000 and winter 2001 only used private organization data for the Twentymile Creek Watershed.

The consistently higher WVSCI scores and the Total Taxa in the Unmined sites relative to Filled sites across six seasons showed that Filled sites have lower biotic integrity than those sites without VFs. Furthermore, reduced taxa richness in Filled sites is primarily the result of fewer pollution-sensitive EPT taxa. The lack of significant differences between these two EIS classes in autumn 1999 appears to be due to the effects of greatly reduced flow in sites draining unmined sites during a severe drought. Continued sampling in Unmined and Filled sites would improve the understanding of whether MTM/VF activities are associated with seasonal variation in benthic macroinvertebrate metrics and base-flow hydrology.

Examination of the Additive sites from the mainstem of Twentymile Creek indicated that impacts to the benthic macroinvertebrate communities increased across seasons and upstream to downstream of Twentymile Creek. In the first sampling season one metric, Total Taxa, was negatively correlated with distance along the mainstem. The number of metrics showing a relationship with cumulative river mile increased across seasons, with four of the six metrics having significant correlations in the final sampling season, Winter 2001. Also in Winter of 2001, a regression of the WVSCI versus cumulative river kilometer estimates a decrease of approximately one point in the WVSCI for each river kilometer. Season and cumulative river kilometer in this dataset may be surrogates for increased mining activity in the watershed.

6. LITERATURE CITED

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APPENDIX A

SUMMARY TABLES OF PROTOCOLS AND PROCEDURES USED BY THE FOUR ORGANIZATIONS TO COLLECT DATA FOR THE MTM/VF STUDY

Table A-1. Habitat assessment procedures used by the four organizations participating in the MTM/VF Study.

Habitat Assessment Procedures				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Site Selection Criteria	The watershed to be assessed began at least one receiving stream downstream of the mining operation and extended to the headwaters. Monitoring stations were positioned downstream in a similar watershed representative of the future impact scenario. Where possible, semi-annual samples were taken where baseline data were collected. Following Phase II, but prior to final release, samples to be taken where mining phase data were collected. See benthic macroinvertebrate procedures for further details.	No information on habitat data collection given.	Based on agreement reached between the client and regulatory agencies. Sites were selected to provide quantitative, site specific identification and characterization of sources of point and non-point chemical contamination.	No information on habitat data collection given.
Methods Used	Habitat assessment made according to Barbour et al. (1999). Riparian habitat and substrate described using Kaufmann and Robison (1998). Habitat assessment is made as a part of the benthic macroinvertebrate survey.	No information on habitat data collection given.	Habitat assessments performed at the same reach from which biological sampling was conducted. Used the protocols in Kaufmann and Robison (1998) or Barbour et al. (1999).	No information on habitat data collection given.
Procedures	A habitat assessment made according to Barbour et al. (1999) and the riparian habitat and substrate described using Kaufmann and Robison (1998).	No information on habitat data collection given.	A single habitat assessment form which incorporated the features of the sampling reach and of the catchment area was completed. Habitat evaluations were made first on instream habitat, followed by channel morphology, bank structural features and riparian vegetation.	No information on habitat data collection given.

(Continued)

Table A-1. Continued.

Habitat Assessment Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Habitat QA/QC	A habitat assessment made according to Barbour et al. (1999) and the riparian habitat and substrate described using Kaufmann and Robison (1998).	No information on habitat data collection given.	Accepted QA/QC practices were employed during habitat assessment. The habitat evaluations were conducted by a trained field biologist immediately following the biological and water quality sampling. The completed habitat assessment form was reviewed by a second field biologist before leaving the sampling reach. The biologists discussed the assessment. Photographs of the sampling reaches were collected and used as a basis for checks of the assessments. The habitat data were entered into a database, then they were checked against the field sheets.	No information on habitat data collection given.

Table A-2. Parameters and condition categories used in the U.S. EPA's RBP for habitat.

RBP Habitat Parameter	Condition Category			
	Optimal	**Sub-optimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover **(high and low gradient)**	Greater than 70% (50% for low gradient streams) of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/ snags that are not new fall and not transient).	40-70% (30-50% for low gradient streams) mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of new fall, but not yet prepared for colonization (may rate at high end of scale).	20 - 40% (10-30% for low gradient streams) mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% (10% for low gradient streams) stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**
2. Embeddedness **(high gradient)**	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**
3. Velocity/Depth Regimes **(high gradient)**	All four velocity/depth regimes present (slow-deep, slow- shallow, fast-deep, fast-shallow). (Slow is <0.3 m/s, deep is >0.5 m).	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**
4. Sediment Deposition **(high and low gradient)**	Little or no enlargement of islands or point bars and less than 5% (<20% for low-gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition f new gravel, sand or fine sediment on old and new bars; 30-50% 50-80% for low-gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**
5. Channel Flow Status **(high and low gradient)**	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**

(Continued)

Table A-2 (Continued).

6. Channel Alteration **(high and low gradient)**	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization (i.e., dredging, greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. In-stream habitat greatly altered or removed entirely.
SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**
7. Frequency of Riffles (or bends) **(high gradient)**	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuos, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 and 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 and 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**
8. Bank Stability (score each bank) **(high and low gradient)**	Banks stable: evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE_____ LB	**Left Bank 10 9**	**876**	**543**	**210**
SCORE_____ RB	**Right Bank 10 9**	**876**	**543**	**210**
9. Bank Vegetative Protection (score each bank) **(high and low gradient)**	More than 90% of the stream bank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the stream bank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the stream bank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one half of the potential plant stubble height remaining.	Less than 50% of the stream bank surfaces covered by vegetation; disruption of stream bank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE_____ LB	**Left Bank 10 9**	**876**	**543**	**210**
SCORE_____ RB	**Right Bank 10 9**	**876**	**543**	**210**

(Continued)

Table A-2 (Continued).

10. Riparian Vegetation Zone Width (score each bank riparian zone) **(high and low gradient)** **SCORE_____ LB** **SCORE_____ RB**	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear- cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
	Left Bank 10 9	**876**	**543**	**210**
	Right Bank 10 9	**876**	**543**	**210**

Table A-3. Substrate size classes and class scores.

Class	Size	Class Score	Description
Bedrock	> 4000 mm	6	Bigger than a car
Boulder	250 to 4000 mm	5	Basketball to car
Cobble	64 to 250 mm	4	Tennis ball to basketball
Coarse Gravel	16 to 64 mm	3.5	Marble to tennis ball
Fine Gravel	2 to 16 mm	2.5	Ladybug to marble
Sand	0.06 to 2 mm	2	Gritty between fingers
Fines	< 0.06 mm	1	Smooth, not gritty

Table A-4. Water quality assessment procedures used by the four organizations participating in the MTM/VF Study.

Water Quality Procedures				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Site Selection Criteria	The watershed to be assessed began at least one receiving stream downstream of the mining operation and extended to the headwaters. Monitoring stations were positioned downstream in a similar watershed representative of the future impact scenario. Where possible, semi-annual samples were taken where baseline data were collected. Following Phase II, but prior to final release, samples to be taken where mining phase data were collected. See benthic macroinvertebrate procedures for further details.	No information on water quality assessment given.	Based on agreement reached between the client and regulatory agencies. Sites were selected to provide quantitative, site specific identification and characterization of sources of point and non-point chemical contamination.	Not specified in Comprehensive QA Plan.
Methods Used to Make Water Quality Measurements in the Field	Stream flow was measured. Temperature, pH, DO, and conductivity were also measured.	No information on water quality assessment given.	Stream flow was measured at or near the sampling point using techniques in Kaufmann (1998). The data were recorded on a field form. Temperature, pH, DO and conductivity measurements were made using protocols in U.S. EPA (1983). These parameters were measured *in situ* at all sites and recorded on field sheets. The measurements were made directly upstream of the biological sampling site.	Characteristics (i.e., size, depth and flow) and site location are recorded.

(Continued)

Table A-4. Continued.

Water Quality Procedures (Continued)				
	U.S, EPA Region 3	**BMI**	**POTESTA**	**REIC**
Sample Collection	Samples were collected in accordance with Title 40, Chapter I, Part 136 of the Code of Federal Regulations.	No information on water quality assessment given.	Field personnel collected grab samples at each station in conjunction with and upstream of benthic macroinvertebrate sampling events. Water samples were labeled in the field. Samples were collected in accordance with Title 40, Chapter I, Part 136 of the Code of Federal Regulations.	Grab samples are collected with a transfer device or with the sample container. Transfer devices are constructed of inert materials. Samples are placed in appropriate containers. Samples are labeled in the field.
Preservation	Samples were preserved in accordance with Title 40, Chapter I, Part 136 of the Code of Federal Regulations.	No information on water quality assessment given.	Samples were preserved in the field	Samples are preserved in the field. Samples are placed in temperature controlled coolers (4^{o} C) immediately after sampling
Laboratory Transfer	No guidance on water sample transport given.	No information on water quality assessment given.	Samples were transferred to a state-certified laboratory for analysis. Chain-of-custody forms accompanied samples to the laboratory.	Samples are delivered to the laboratory as soon as possible. A chain-of-custody record accompanies each set of samples.

(Continued)

Table A-4. Continued.

Water Quality Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Parameters Analyzed in the Laboratory	Recommended Parameters: dissolved iron dissolved manganese dissolved aluminum calcium magnesium sodium potassium chloride total suspended solids total dissolved solids alkalinity acidity sulfate dissolved organic carbon hardness nitrate/nitrite total phosphorous	No information on water sample analyses given.	alkalinity acidity total suspended and dissolved solids sulfate nitrate/nitrite total phosphorus chloride sodium potassium calcium magnesium hardness total iron total and dissolved manganese total and dissolved aluminum total antimony total arsenic total beryllium total cadmium total chromium total copper total lead total mercury total nickel total selenium total silver total thallium total zinc coarse particulate organic matter fine particulate organic matter total organic carbon	Not specified for this project in the QA Plan.
General QA/QC	A QA/QC plan should be developed.	No information on water chemistry QA/QC practices given.	Accepted QA/QC practices are employed during sampling and analysis.	QA/QC practices are detailed in REI Consultants, Inc. (2001).

(Continued)

Table A-4. Continued.

Water Quality Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Field QA/QC	A QA/QC plan should be developed.	No information on water chemistry QA/QC practices given.	Temperature, pH, DO and conductivity measurements are made using protocols in U.S. EPA (1983). Dissolved oxygen and pH meters are calibrated daily. Calibrations are checked after unusual readings and adjusted if needed. All probes are thoroughly rinsed with distilled water after all calibrations and between sampling sites.	No information on field measurement QA/QC practices given.
Sample Collection QA/QC	A QA/QC plan should be developed.	No information on sample collection QA/QC practices given.	All containers and lids are new. All containers, preservatives and holding times meet the requirements given in Title 40 (Protection of the Environment), Part 136 (Guidelines Establishing Test Procedures for the Analysis of Pollutants) of the Code of Federal Regulations. Each container is labeled with the site identification, date and preservative. Chain-of custody forms are filled out for each group of samples and accompany the samples to a state-certified laboratory.	No information on sample collection QA/QC practices given.
Laboratory QA/QC	A QA/QC plan should be developed.	No information on water sample analysis laboratory QA/QC practices given.	The laboratory analysis of water chemistry follows Standard Methods and/or EPA approved methods. Any deviations from these methods are noted.	No information on water sample analysis laboratory QA/QC practices given.

Table A-5. Fish assemblage assessment procedures used by the four organizations participating in the MTM/VF Study.

Fish Procedures				
	U.S. EPA Region 3 (PSU)	**BMI**	**POTESTA**	**REIC**
Site Selection Criteria	At least one site was established at the most downstream extent of the impact area. This site was permanently recorded and revisited annually. See benthic macroinvertebrate procedures for further details.	No information on fish data collection given.	Sites were designated in consultation with regulatory agencies.	1) Within vicinity of macroinvertebrate and water quality sampling locations. 2) Reaches contained variety of habitat, cover, water velocities and depths. 3) Representative of the stream. 4) If bracketing a confluence, were as close to the tributary as possible, while allowing a downstream buffer for mixing. 5) If used for comparative purposes, contained similar amounts of fish habitat and cover and frequency of riffles and pools.
Station Preparation	Protocols generally followed those in McCormick and Hughes (1998). The stream reach was 40 times the wetted width of the stream, with a maximum reach of 150 m.	No information on fish data collection given.	Stream reach lengths were at least 40 times the stream width and did not exceed 150m.	A stream reach of 150 m was used. Block nets of ↗-in mesh were set perpendicular to stream by approaching from the shore. Nets were set tight against the substrate and remained in place throughout the survey.
Electrofishing Procedures	Protocols generally followed those in McCormick and Hughes (1998). Block nets were set at the ends of the reach. Amps, voltage and pulse were set according to the stream's conductivity. The surveys began at the downstream end of the reach and proceeded upstream. Netters retrieved the fish and placed them in buckets. The fish were processed at the end of each transect. The survey proceeded until all transects had been fished.	No information on fish data collection given.	Fish were collected at each site using a backpack electrofishing unit. Collections began at the downstream end of the reach and proceeded upstream for the entire reach. Fish collected during the first pass were placed in a bottle labeled "Collection #1". Two additional passes were made and fish from the second and third pass were placed in bottles labeled "Collection #2" and "Collection #3, respectively. If the number of fish in the latter passes did not decline from the previous pass, additional passes	Surveys were conducted in first-, second- and third-order streams by a backpack electrofishing unit. The output voltage and pulse frequency were controlled by the biologist. The biologist progressed slowly upstream moving the wands across the entire stream width. Technicians positioned on each side of the biologist netted the stunned fish and placed them in buckets

			were made.	containing water. Three passes were conducted at each station.

(Continued)

Table A-5. Continued.

Fish Procedures (Continued)				
	U.S. EPA Region 3 (PSU)	**BMI**	**POTESTA**	**REIC**
Field Measurements	Fish were identified, tallied and examined for external anomalies. The standard length of each fish was measured to the nearest mm and each fish was weighed to the nearest 0.01 g.	No information on fish data collection given.	Fish from each pass were kept separate. Game fish (except small specimens) and rare, threatened or candidate species were counted, measured (total length), weighed and released. These data were recorded on field sheets. The majority of fish captured were preserved in 10% formalin and taken to the laboratory. Each collection was preserved separately.	After each pass, fish were identified, measured to the nearest mm of total length and weighed to the nearest 0.1 gm or 1.0 gm (depending on fish size). Large fish were held in a live well until the completion of the survey, then released to their original reach. Small fish requiring microscopic verification were preserved in 10% formalin and taken to the laboratory.
Specimen Preparation, Identification and Validation	Fish were labeled and preserved in 10% formalin and transported to the PSU Fish Museum where they were deposited for permanent storage in 50% isopropanol. Voucher collections of up to 25 individuals of each taxon collected (except very large individuals of easily identified species) were prepared.	No information on fish data collection given.	Preserved specimens were taken to the laboratory and temporarily stored in 50% isopropanol or 10% ethanol. They were identified and weighed. All preserved fish were placed in permanent storage in a recognized museum collection or offered for use in the federal EIS on MTR/VF mining in West Virginia.	Small fish were identified in the laboratory. All fish were sorted by species and their identities were verified when they were weighed to the nearest 0.1 gm and their total lengths were measured. Identified fish were stored. Unidentified fish were identified and validated by West Virginia DNR personnel.
Fish Data Analysis	Total biomass caught, biomass per m^2 sampled and abundances of each species were calculated.	No information on fish data analysis given.	Fish data sheets were transferred into spreadsheets. Data entered into the spreadsheets were routinely checked against field and laboratory sheets immediately following data entry. Any discrepancies were documented and corrected. Population and community structure were determined at each site. Age classes based on length,	Data were entered into a spreadsheet and confirmed. At each sampling station, total taxa, number and percent of pollution-intolerant fish, number and percent of intermediately pollution- tolerant fish, Number and percent of pollution-tolerant fish, Shannon-Weiner diversity Index, Percent species similarity index were made. For each

			frequency analysis and standing crop (kg/ha) were calculated for each species at each pass.	species at each sampling station, Total abundance, Mean length, Mean weight, Standing stock, and Sensitivity index (U.S. EPA 1999) were calculated.

(Continued)

Table A-5. Continued.

Fish Procedures (Continued)				
	U.S. EPA Region 3 (PSU)	**BMI**	**POTESTA**	**REIC**
Fish Population Estimates	No information on fish population estimates given.	No information on fish data analysis given.	Population estimates of each species at each site were made using the triple pass depletion method of Van Deventer and Platts (1983).	Population estimates for each species and each reach were calculated using the Zippin (1956) depletion method and based on observed relative abundance. Total fish weight by species was extrapolated to calculate an estimated total standing stock.
Fish Identification and Verification QA/QC	The interim protocols stated that a QA/QC plan should be developed.	No information on fish data QA/QC given.	Implemented the QA/QC plan from the U.S. Geological Survey (Walsh and Meador 1998). The plan outlines methods used to ensure accurate identification of fish collected. A voucher collection including one specimen of each taxon collected was made available for verification. Data entered into spreadsheets were routinely checked against field and laboratory sheets.	The QA/QC protocols called for the use of two Fisheries Biologists with the appropriate qualifications: Any species captured whose distribution did not match Stauffer et al. (1995) was recorded and the identification was confirmed by West Virginia DNR personnel. All identifications were confirmed by both Fisheries Biologists. Small fish which required microscopic identification were stored for future reference or identification. A reference collection of all captured taxa was kept. Any species of questionable identification were kept and verified by West Virginia DNR personnel. All retained specimens were permanently labeled.

Table A-6. Macroinvertebrate assemblage assessment procedures used by the four organizations participating in the MTM/VF Study.

Benthic Macroinvertebrate Procedures				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Site Selection Criteria	The watershed to be assessed began at least one receiving stream downstream of the mining operation and extended to the headwaters. Monitoring stations were positioned downstream in a similar watershed representative of the future impact scenario. Where possible, semi-annual samples were taken where baseline data were collected. A minimum of two stations were established for each intermittent and perennial stream where fills were proposed. One station was as close as possible to the toe of the fill and the other was downstream of the sediment pond location. If the sediment pond was more than 0.25 mi from the toe of the fill, a third station was placed between the two. Additional stations were placed in at least the first receiving stream downstream of the mining operation.	BMI located one sampling station as close as possible to the toe of the proposed VF. Another sampling station was located below the proposed sediment pond. If the proposed sediment pond was to be > 0.25 miles below the toe of the fill, an additional station was located between the toe of the fill and the sediment pond. Two sampling stations were located within the next order receiving stream downstream. One of these stations was located above the confluence and one was located below the confluence. In general, an unmined reference station was located at a point that represented the area proposed for mining. In addition, a mined and filled reference station was located at a point that represents a similar level of mining.	Based on an agreement reached between the client and regulatory agencies. Selected to provide quantitative and qualitative characterizations of benthic macroinvertebrate communities.	The sampling station locations contained habitat which was representative of the overall habitat found within stream reach. Stations that were to be used for comparative purposes contained similar habitat characteristics. Stations bracketing a proposed fill tributary were close (approximately 100 m) to the impacted tributary. The general locations were usually pre-determined by the client and the permit writer. When descriptions of predetermined sites were vague, professional judgements were made in an attempt to incorporate the studies' goals. For selecting sampling sites for proposed VFs, site were located at the toe of the valley, below the sediment pond at the mouth of the fill stream, upstream and downstream of the fill stream on the receiving stream and on the next order receiving stream.

(Continued)

Table A-6. Continued.

Benthic Macroinvertebrate Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Sampling Point selection	The sampling point was at the middle of the reach. It was moved upstream or downstream to avoid tributary effects, bridges or fords.	No information given on specific sampling point selection.	No information given on specific sampling point selection.	One of three methods (i.e., completely randomized, stratified-random or stratified) was used to select the sampling points at a site. Generally, the stratified-random method was used in large streams and the stratified method was used in small streams. In small intermittent streams or when there was little water, samples were taken from wherever possible.
Sampler Used	Sampling was conducted according to Barbour et al. (1999). A 0.5-m rectangular kick net was used to composite four ¼-m^2 samples.	In the autumn of 1999 and the spring of 2000, four ¼-m^2 samples collected with a D-frame kick net were composited. In the autumn of 2000, six Surber samples were collected and four ¼-m^2 samples collected with a D-frame kick net were composited. In the spring of 2001, four Surber samples, were collected and four ¼-m^2 samples were collected with a D-frame kick net and composited.	Four ¼-m^2 samples were taken using a D-frame kick net and composited. Surber samplers were used at selected sampling stations.	The sampling devices were dependent on the permit. Three samples were taken using a Surber sampler. These were not composited. Four ¼-m^2 samples were taken using a D-frame kick net. These were composited. The Surber samplers were usually used in riffle areas and the kick net samples were usually taken from deeper run or pool habitats.
Surber Sampler Procedures	Surber samplers were not used.	The frame of the sampler was placed on the stream bottom in the area that was to be sampled. All large rocks and debris that are in the 1.0-ft^2 frame were scrubbed and rinsed into the net and removed from the sampling area. Then, the substrate in the frame was vigorously disturbed for 20 seconds. Each sample was rinsed and placed into a labeled container with two additional labels inside the sample containers.	The Surber sampler was placed with all sides flat on the stream bed. Large cobble and gravel within the frame were brushed. The area within the frame was disturbed to a depth of three in with the handle of the brush. The sample was transferred to a labeled plastic bottle.	The sampler was placed with the cod end downstream. The substrate upstream of the sampler was scrubbed gently with a nylon brush for up to three minutes. Water was kept flowing into sampler while scrubbing. Rocks were checked and any clinging macroinvertebrates were removed and placed in the sampler. The material in the sampler was rinsed and collected into a bottle.

Table A-6. Continued.

Benthic Macroinvertebrate Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Kick Net Procedures	The procedures in Barbour et al. (1999) were modified so that 1 m^2 of substrate was sampled at each site.	The net was held downstream of the 0.25-m^2 area that was to be sampled. All rocks and debris that were in the 0.25-m^2 area were scrubbed and rinsed into the net and removed from the sampling area. Then, the substrate in the 0.25-m^2 area was vigorously disturbed for 20 seconds. This process was repeated four times at each sampling site. The composited sample was rinsed and placed into a labeled container.	The kick net samples were collected using protocols in Barbour et el. (1999). All boulders, cobble and large gravel within 0.25 m^2 upstream of net were brushed into the net. The substrate within 0.25 m^2 upstream of the net was kicked for 20 seconds. Four samples were collected and composited. The sample was transferred to a labeled plastic bottle.	The sampler was placed with the net outstretched and the cod end downstream. The substrate was kicked or scrubbed for up to three minutes. Discharged material was swept into the net. An area of approximately 0.25m^2 was sampled. The procedure was repeated four times.
Additional information collected from sites	The physical/chemical field sheets were completed before sampling and they were reviewed for accuracy after sampling. A map of the sampling reach was drawn. A GPS unit was used to record latitude and longitude. After sampling, the Macroinvertebrate Field Sheet was completed. The percentage of each habitat type in the reach was recorded and the sampling gear used was noted. Comments were made on conditions of the sampling.. Observations of aquatic flora and fauna were documented. Qualitative estimates of macroinvertebrate composition and relative abundance were made. A habitat assessment	Additional information collected was not described.	A field data sheet (from Barbour et al. 1999) was completed and photographic documentation was taken at the time of sampling. Photographs showed an upstream view and a downstream view from the center of the sampling reach.	Additional information collected was not described.

	was made. Riparian habitat was described using Kaufmann and Robison (1998).			

(Continued)

Table A-6. Continued.

Benthic Macroinvertebrate Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Sample Preservation	Samples were preserved in 95% ethanol.	Samples were preserved in 70% ethanol.	Quantitative samples were preserved in 50% isopropanol. Semi-quantitative samples were preserved in either 50% isopropanol or 70% ethanol.	Samples were preserved in the field with formaldehyde (30% by wt.). Approximately 10% of the samples' volume was added.
Logging samples	All samples were dated and recorded in a sample log notebook upon receipt by laboratory personnel. All information from the sample container label was included on the sample log sheet (Barbour et al. 1999).	Samples were logged onto Chain-of-Custody forms. Logs were maintained throughout the identification process.	When samples arrived at the laboratory, they were entered in a log book and tracked through processing and identification.	Sample logging procedure was not described.
Laboratory Procedures	Samples were thoroughly rinsed in a 500 µm-mesh sieve. Large organic material was rinsed, visually inspected, and discarded. Samples that had been preserved in alcohol, were soaked in water for approximately 15 minutes. Samples stored in more than one container were combined. After washing, the sample was spread evenly across a pan marked with grids approximately 6 cm x 6 cm. A random numbers table was used to select four grids. All material from the four grids (↗ of the total sample) was removed and placed in a shallow white pan. A predetermined, fixed number of organisms were used to determine when sub-sampling was complete.	Samples were rinsed using a #24 sieve (0.0277-in mesh) and then transferred to an enamel tray. Water was added to the tray to a level that covered the sample. All macroinvertebrates in the sample were picked from the debris using forceps and then transferred to a vial that contained 70% ethanol. One of the labels from the sample jar was placed on the organism vial. After identification and processing, the samples were then stored according to the project plan.	Benthic macroinvertebrates were processed using the single habitat protocols in Barbour et al. (1999). The entire samples were processed. Identifications were recorded on standard forms. Ten percent of the samples are re-picked and identifications are randomly reviewed.	Samples were processed individually. They were poured into a 250-µm sieve. Then rinsed with water and transferred to a four-part sub-sampler with a 500-µm screen and distributed evenly on the with water. The first ¼ of the sample was put into petri dishes and the aquatic insects were sorted from the detritus. All macroinvertebrates were placed in a labeled bottle with formalin. If too few individuals were found in the ¼, the second ¼ was picked. Then, either a portion of the picked detritus was re-checked, or a single

				sorter checked all petri dishes. If organisms were present, the sample was re-picked. After sample sorting was complete, picked and unpicked detritus was stored.

(Continued)

Table A-6. Continued.

Benthic Macroinvertebrate Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Benthic Macro-invertebrate Identification	Organisms were identified to the lowest practical taxon by a qualified taxonomist. Each taxon found in a sample was recorded and enumerated in a bench notebook and then transcribed to the laboratory bench sheet for subsequent reports. Any difficulties encountered during identification were noted on these sheets. Labels with specific taxa names were added to the vials of specimens. The identity and number of organisms were recorded on the bench sheet. Life stages of organisms were also recorded (Barbour et al. 1999).	Using a binocular compound microscope, each organism was identified to the taxa level specified in the project study plan. The numbers of organisms found in each taxa were recorded on bench sheets. Then, the organisms and sample label were returned to the organism vial and preserved with 70% ethanol. For QC purposes, 10% of all samples were re-identified.	Samples were identified by qualified freshwater macroinvertebrate taxonomists to the lowest practical taxon.	Aquatic insects were identified under a microscope to the lowest practical taxonomic level. Unless specified otherwise, Chironomids were identified to the Family level and Annelids were broken into classes. Identified specimens were returned to the sample bottle and preserved in formalin. New or extraordinary taxa were added to reference collections. Random samples are re-identified periodically.
Macro-invertebrate Sample Storage	Samples were stored for at least six months. Specimen vials were placed in jars with a small amount of 70% ethanol and tightly capped. The ethanol level in these jars was examined periodically and replenished as needed. A label was placed on the outside of the jar indicating sample identifier, date, and preservative.	No information on sample storage was provided.	No information on sample storage was provided.	Samples were stored for at least six months.
Database Construction	No information on database construction was provided.	No information on database construction was provided.	The data from the taxonomic identification sheets were transferred into spreadsheets. Data entered into the	No information on database construction was provided.

			spreadsheets were routinely checked against field and laboratory sheets.	
Benthic Macro-invertebrate Data Analysis	Data were used to calculate the WVSCI.	No information on data analysis was provided.	Eight bioassessment metrics were calculated for each sampling station.	Twelve benthic macroinvertebrate metrics were calculated for each of the sampling stations. Abundance data from sub-sampling was extrapolated to equal the entire sample amount.

(Continued)

Table A-6. Continued.

Benthic Macroinvertebrate Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Benthic Macro-invertebrate Metrics Calculated	Data were used to calculate the metrics of the WVSCI.	No information on metrics was provided.	1. Taxa Richness 2. Total Number of Individuals 3. Percent Mayflies 4. Percent Stoneflies 5. Percent caddisflies 6. Total Number of EPT Taxa 7. Percent EPT Taxa 8. Percent Chironomidae	1. Taxa Richness 2. Modified HBI: Summarizes overall pollution tolerance. 3. Ratio of Scrapers to Filtering Collectors 4. Ratio of EPTs to Chironomidae 5. Percent of Mayflies 6. Percent of Dominant Family 7. EPT Index: Total number of distinct taxa within EPT Orders. 8. Ratio of Shredders to Total Number of Individuals 9. Simpson's Diversity Index 10. Shannon-Wiener Diversity Index 11. Shannon-Wiener Evenness 12. West Virginia Stream Condition Index: a six-metric index of ecosystem health.

APPENDIX B

IBI COMPONENT METRIC VALUES

Figure B-1. Box plot of the IBI among EIS classes and regional reference sites. All taxa richness metrics were adjusted to a catchment area of 100 km2.

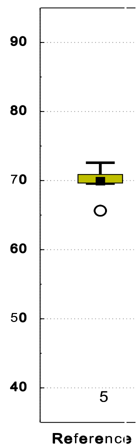


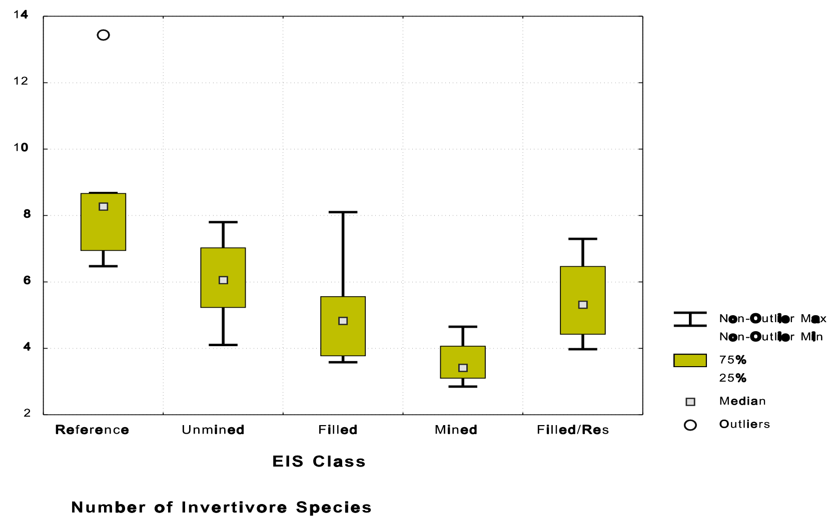
Table B-1. The ANOVA for IBI scores among EIS classes (Unmined, Filled, Mined, and Filled/Residential).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2335.56	778.52	6.70	0.0009
Error	40	4651.31	116.28		
Corrected Total	43	6986.87			

R-Square	Coefficient of Variance	Root MSE	Index Mean
0.334	17.022	10.783	63.350

Table B-2. Dunnett's test comparing IBI values of EIS classes to the Unmined class, with the alternative hypothesis that IBI < Unmined IBI (one-tailed test).

EIS Class	N	Mean	Standard Deviation	Dunnett's P-Value
Filled	17	56.8	10.6	0.0212
Filled/Residential	9	74.6	10.7	0.9975
Mined	4	54.4	13.4	0.0685



Unmined	14	66.7	10.3	--

Figure B-2. Box plot of the Number of Benthic Invertivore Species among EIS classes and regional reference sites.

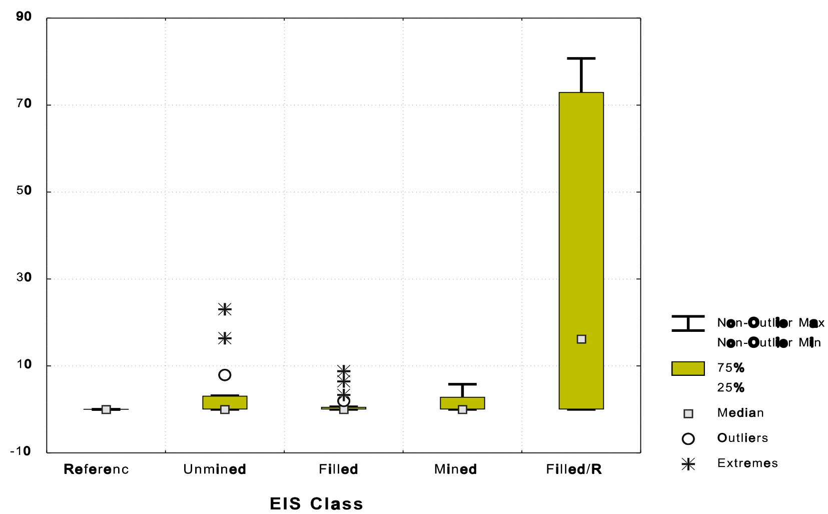
Table B-3. The ANOVA for Number of Benthic Invertivore Species among EIS classes (Unmined, Filled, Mined, and Filled/Residential).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	22.32	7.44	4.91	0.0054
Error	40	60.66	1.51		
Corrected Total	43	82.98			

R-Square	Coefficient of Variance	Root MSE	Index Mean
0.269	23.504	1.231	5.239

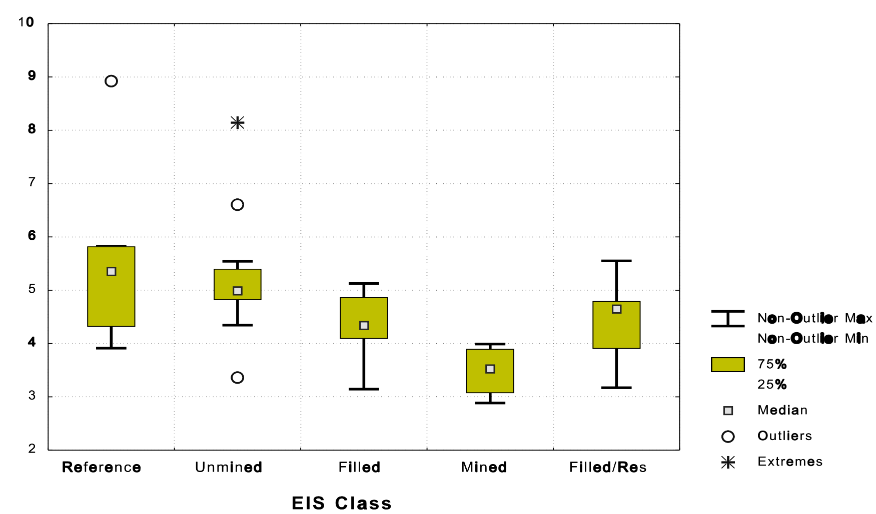
Table B-4. Dunnett's test comparing Numbers of Benthic Invertevores to the Unmined class, with the alternative hypothesis that IBI < Unmined IBI (one-tailed test).

EIS Class	N	Mean	Standard Deviation	Dunnett's P-Value



Percent Sculpins

Filled	17	4.8	1.3	0.0182
Filled/Residential	9	5.4	1.2	0.3234
Mined	4	3.6	0.76	0.0017
Unmined	14	6.0	1.2	--



Minnow Species

Figure B-3. Box plot of the Percent Cottidae(Sculpins) among EIS classes and regional reference sites.

Figure B-4. Box plot of the Number of Native Cyprinidae (Minnow Species)

among EIS classes and regional reference sites. This metric was adjusted to a catchment area of 100 km2.

Table B-5. The ANOVA for Number of Native Cyprinidae (Minnow Species) among EIS classes (Unmined, Filled, Mined, and Filled/Residential).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	11.36	3.79	5.79	0.0022
Error	40	26.19	0.65		
Corrected Total	43	37.56			

R-Square	Coefficient of Variance	Root MSE	Index Mean
0.302	17.777	0.809	4.55

Table B-6. Dunnett's test comparing Numbers of Native Cyprinidae (Minnows Species) to the Unmined class, with the alternative hypothesis that IBI < Unmined IBI (one-tailed test).

EIS Class	N	Mean	Standard Deviation	Dunnett's P-Value
Filled	17	4.3	0.58	0.0089
Filled/Residential	9	4.4	0.73	0.0311
Mined	4	3.5	0.51	0.0008
Unmined	14	5.2	1.1	--

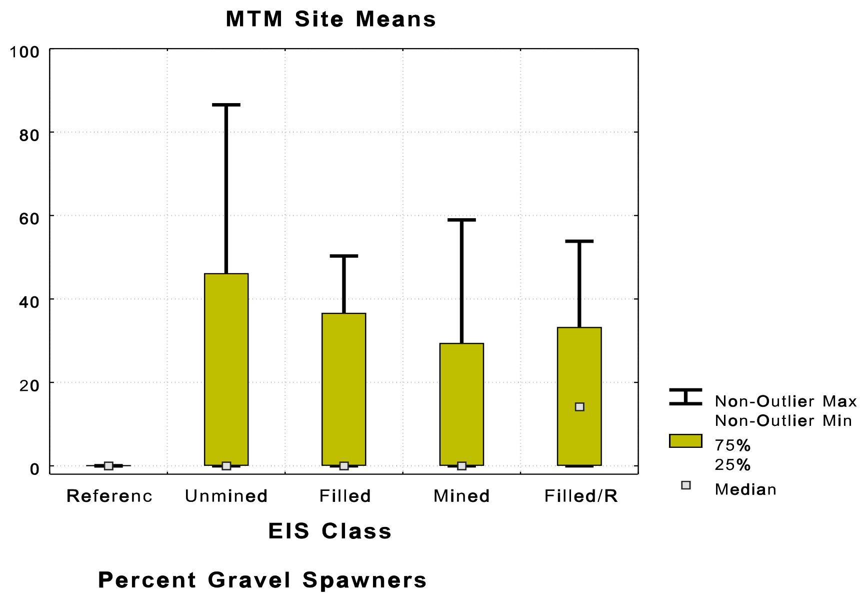


Figure B-5. Box plot of the Percent Gravel Spawners among EIS classes and regional reference sites.

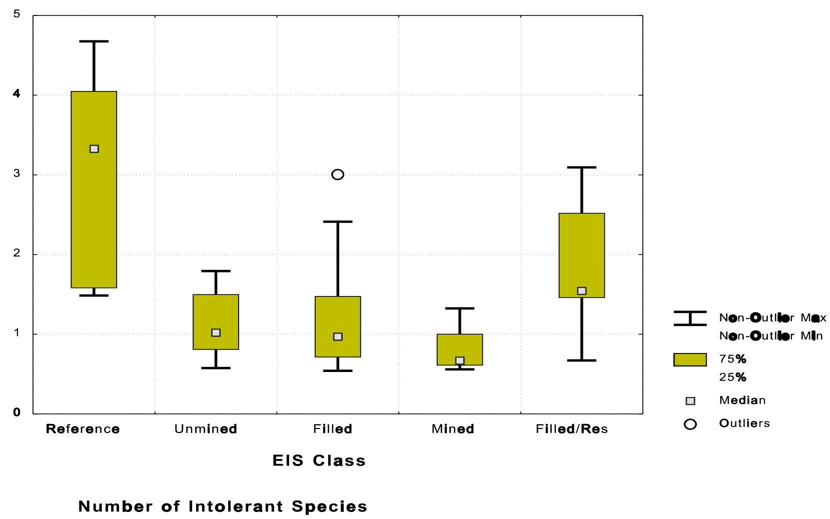
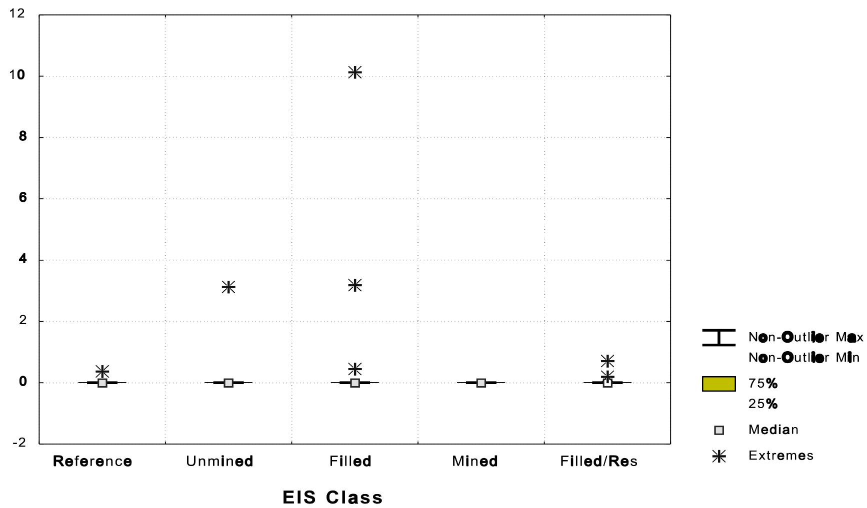


Figure B-6. Box plot of the Percent Piscivore/Invertivores (Predators) among EIS classes and regional reference sites.

Figure B-7. Box plot of the Number of Intolerant Species among EIS classes and regional reference sites. This metric was adjusted to a catchment area of 100 km2.

Table B-7. The ANOVA for Number of Intolerant Species among EIS classes (Unmined, Filled, Mined, and Filled/Residential).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F



Percent non-Native Fish

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	5.29	1.76	5.96	0.0019
Error	40	11.83	0.29		
Corrected total	43	17.12			

R-Square	Coefficient of Variance	Root MSE	Index Mean
0.308	44.209	0.543	1.23

Table B-8. Dunnett's test comparing Numbers of Intolerants to the Unmined class, with the alternative hypothesis that IBI < Unmined IBI (one-tailed test).

EIS Class	N	Mean	Standard Deviation	Dunnett's P-Value
Filled	17	1.1	0.49	0.7075
Filled/Residential	9	1.9	0..83	1.0000
Mined	4	0.8	0.35	0.3504
Unmined	14	1.1	0.40	--

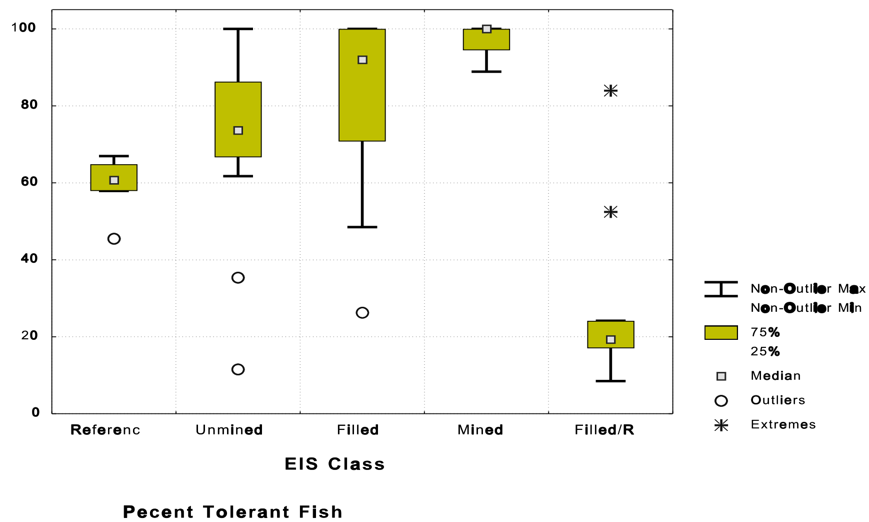


Figure B-8. Box plot of the Percent Exotic (Non-Native Fish) among EIS classes and regional reference sites.

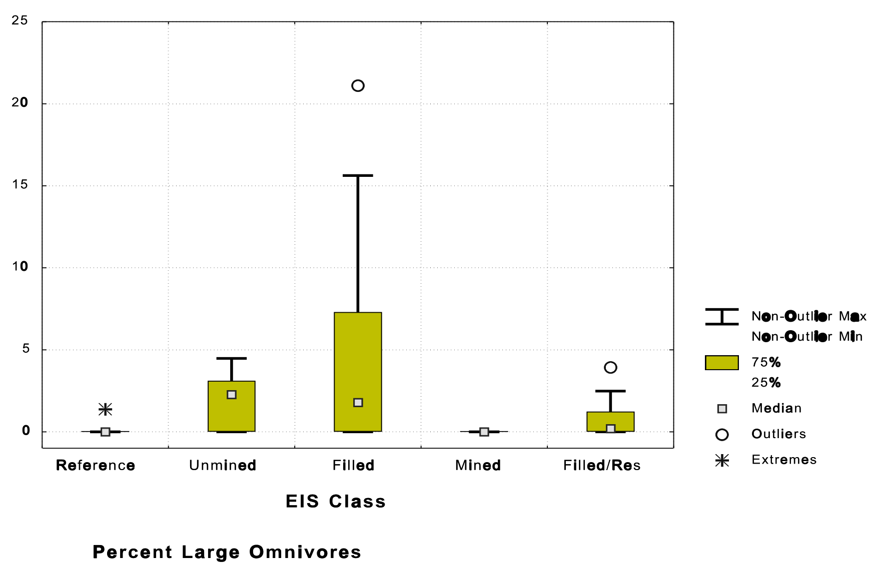


Figure B-9. Box plot of the Percent Macro Omnivores among EIS classes and regional reference sites.
Figure B-10. Box plot of the Percent Tolerant Fish among EIS classes and regional reference sites.

Table B-9. The ANOVA for Number of Tolerant Species among EIS classes

(Unmined, Filled, Mined, and Filled/Residential).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	21001.35	7000.45	14.03	<0.0001
Error	40	19956.38	498.91		
Corrected total	43	40957.73			

R-Square	Coefficient of Variance	Root MSE	Index Mean
0.512	32.055	22.336	69.681

Table B-10. Dunnett's test comparing Numbers of Tolerant Species to the Unmined class, with the alternative hypothesis that IBI < Unmined IBI (one-tailed test).

EIS Class	N	Mean	Standard Deviation	Dunnett's P-Value
Filled	17	82.9	21.5	0.2080
Filled/Residential	9	28.9	24.1	1.0000
Mined	4	97.2	5.6	0.0681
Unmined	14	71.8	24.6	--

APPENDIX C

BOX PLOTS OF THE WVSCI AND COMPONENT METRICS

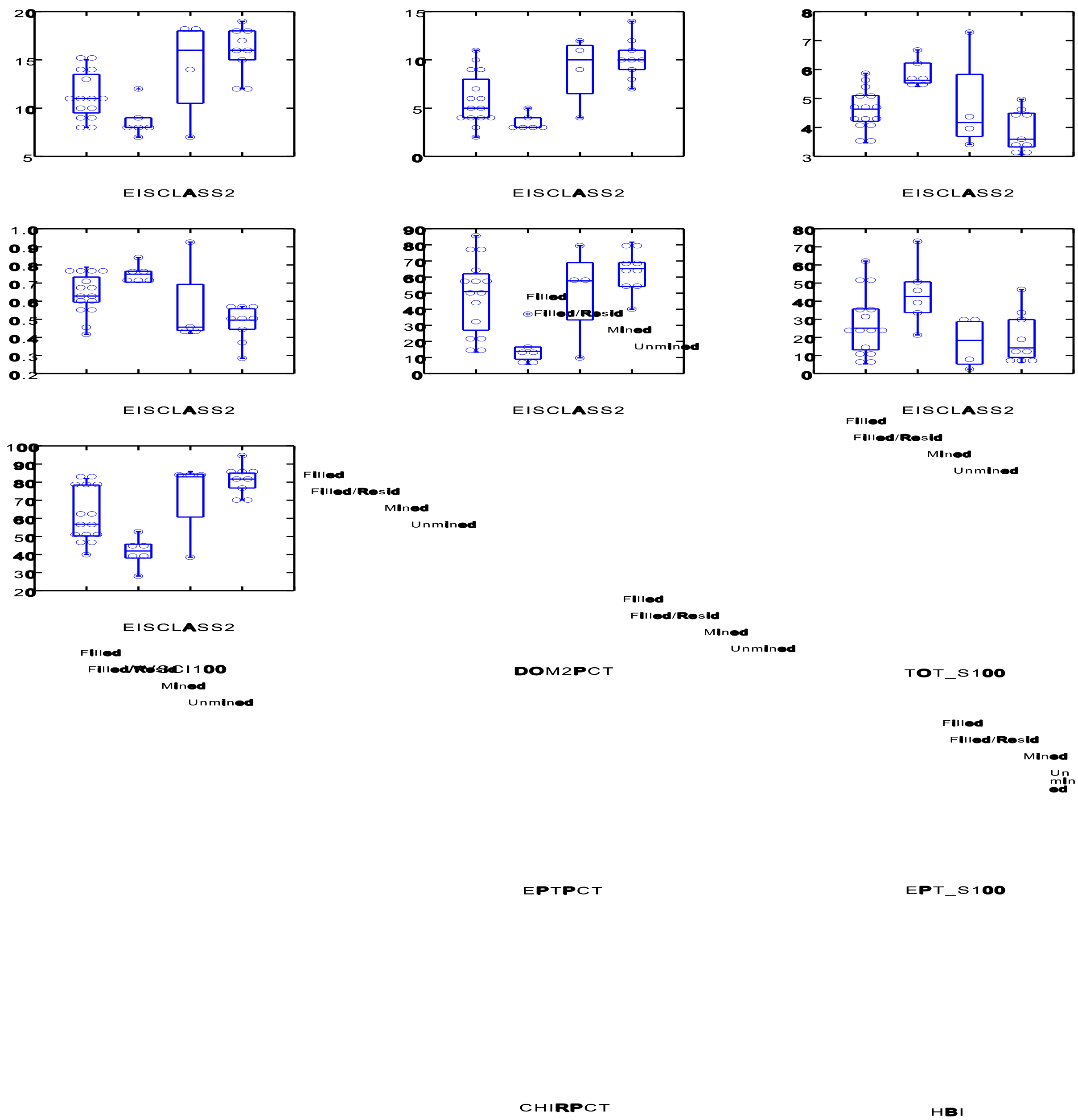


Figure C-1. Box plots of the WVSCI and its component metrics versus the EIS class for the spring 1999 season. Circles represent site scores.

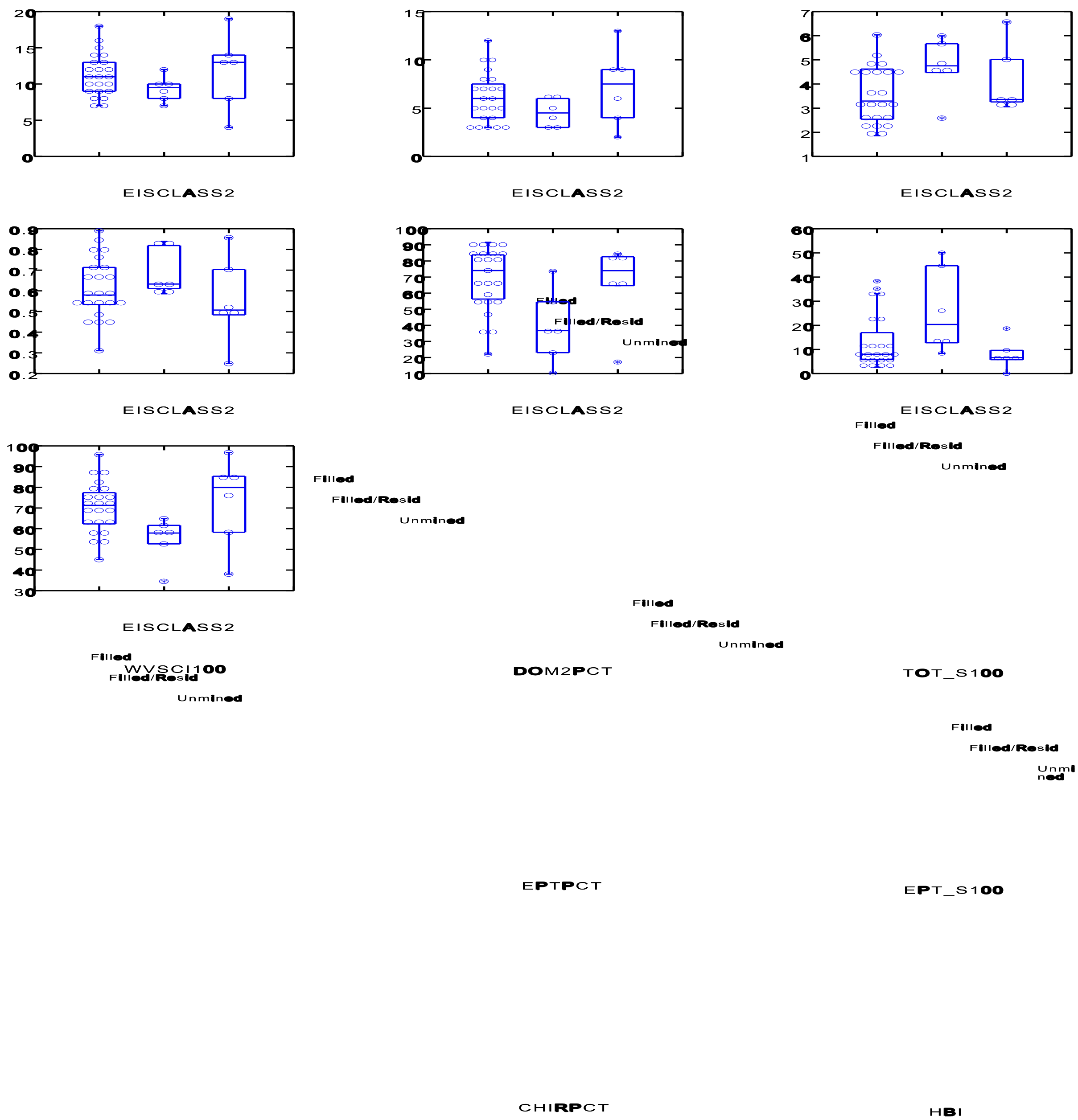


Figure C-2. Box plots of the WVSCI and its component metrics versus the EIS class for the autumn 1999 season. Circles represent site scores.

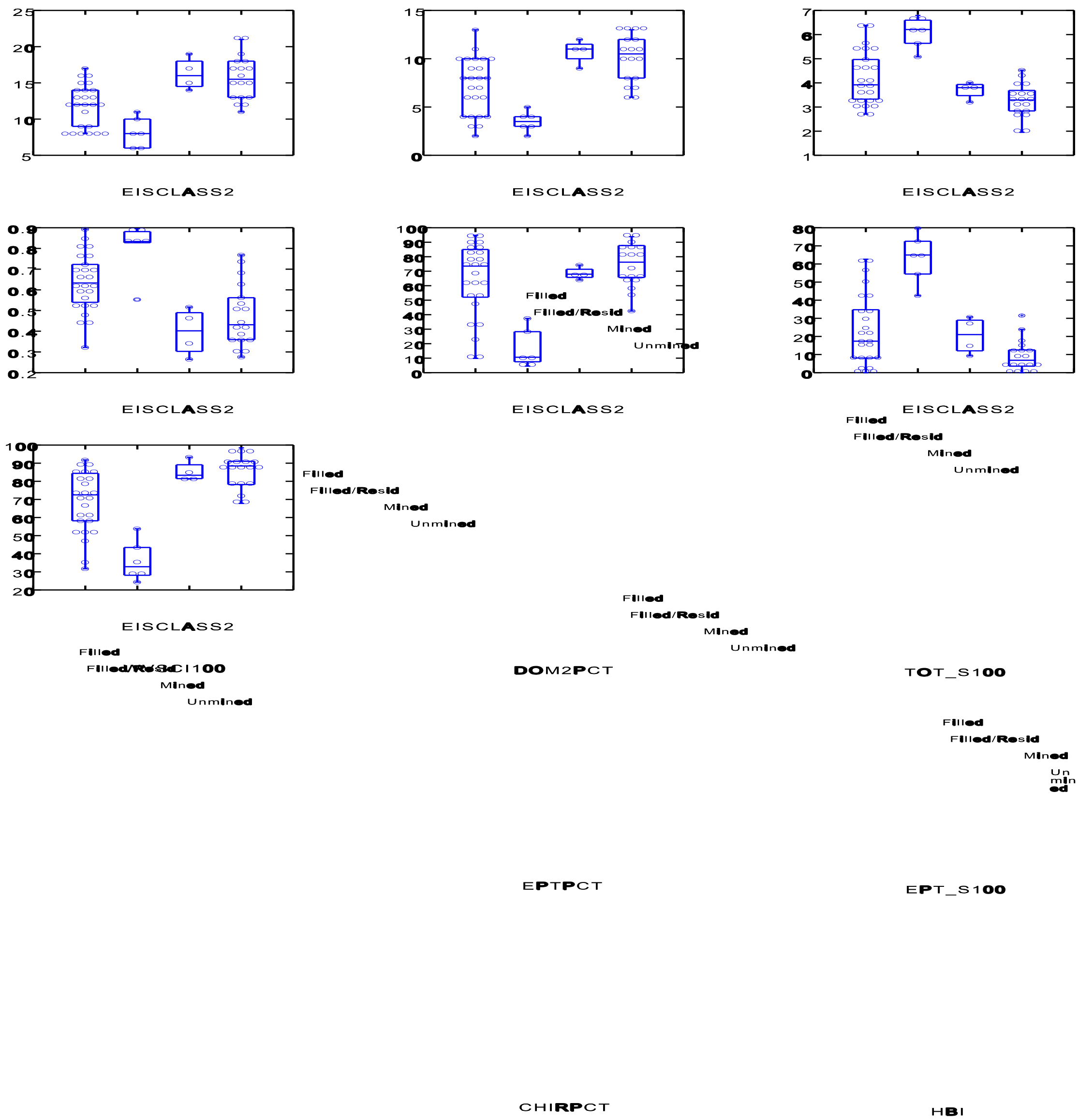


Figure C-3. Box plots of the WVSCI and its component metrics versus the EIS class for the winter 2000 season. Circles represent site scores.

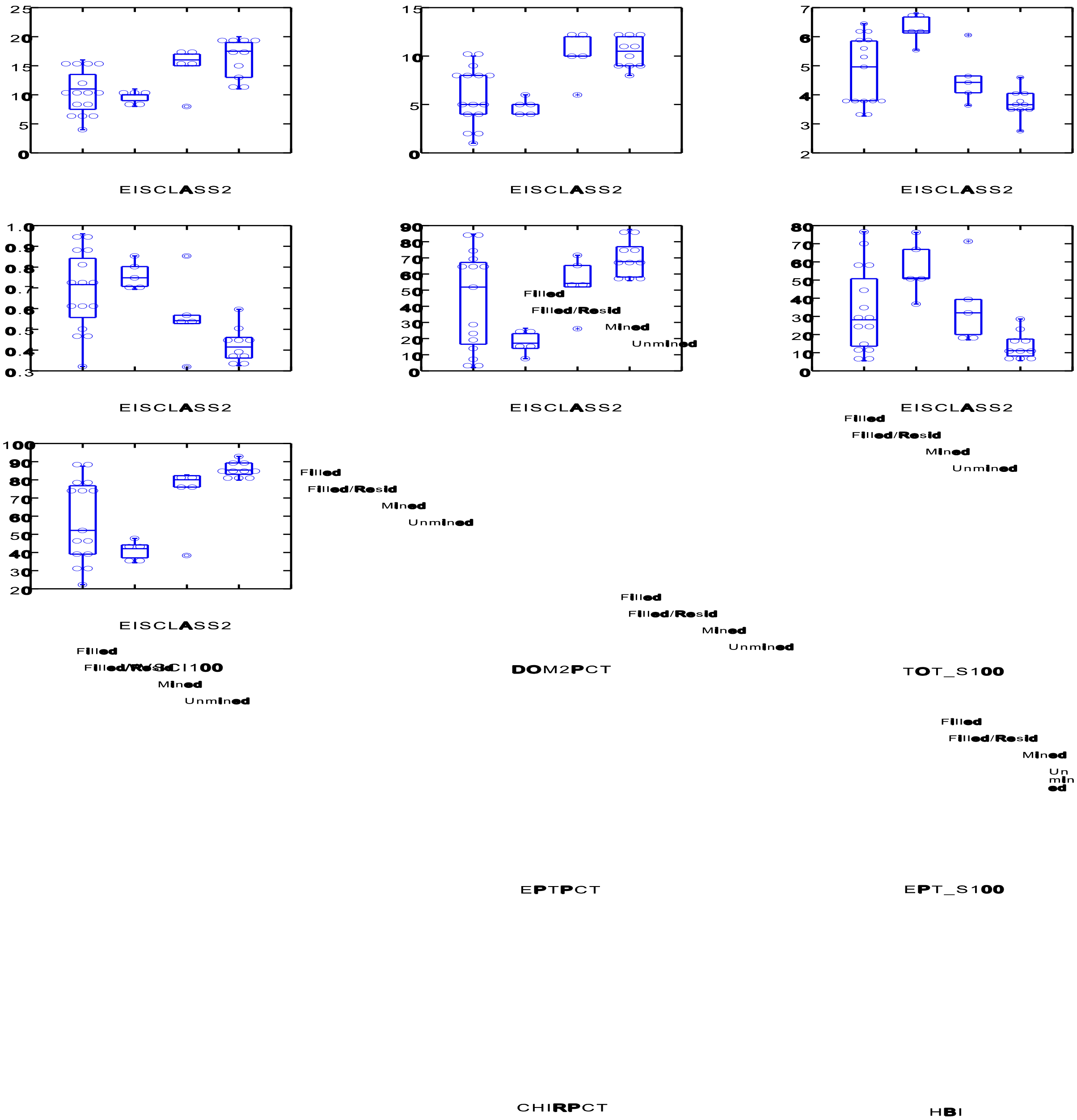


Figure C-4. Box plots of the WVSCI and its component metrics versus the EIS class for the spring 2000 season. Circles represent site scores.

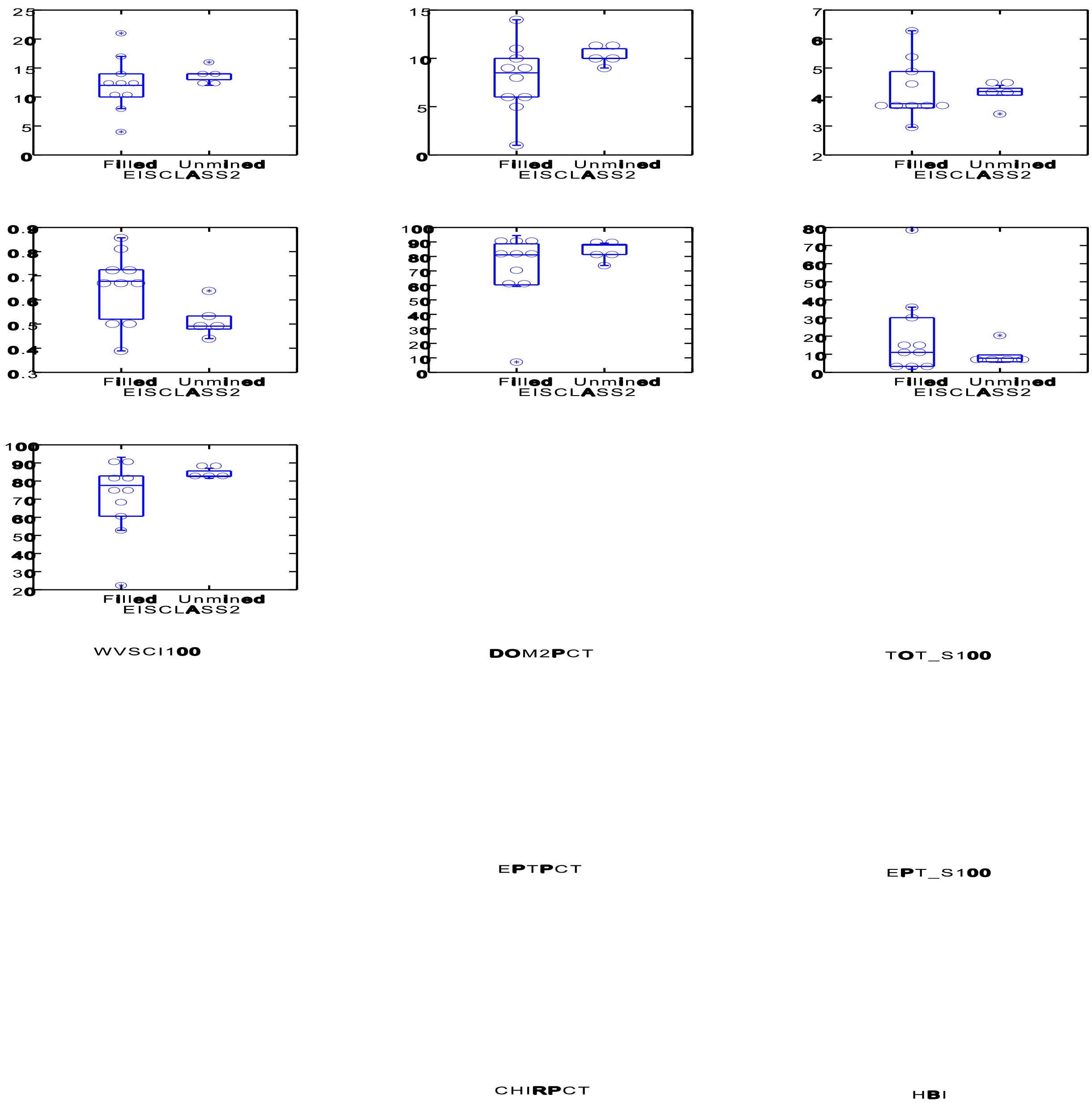


Figure C-5. Box plots of the WVSCI and its component metrics versus the EIS class for the autumn 2000 season. Circles represent site scores.

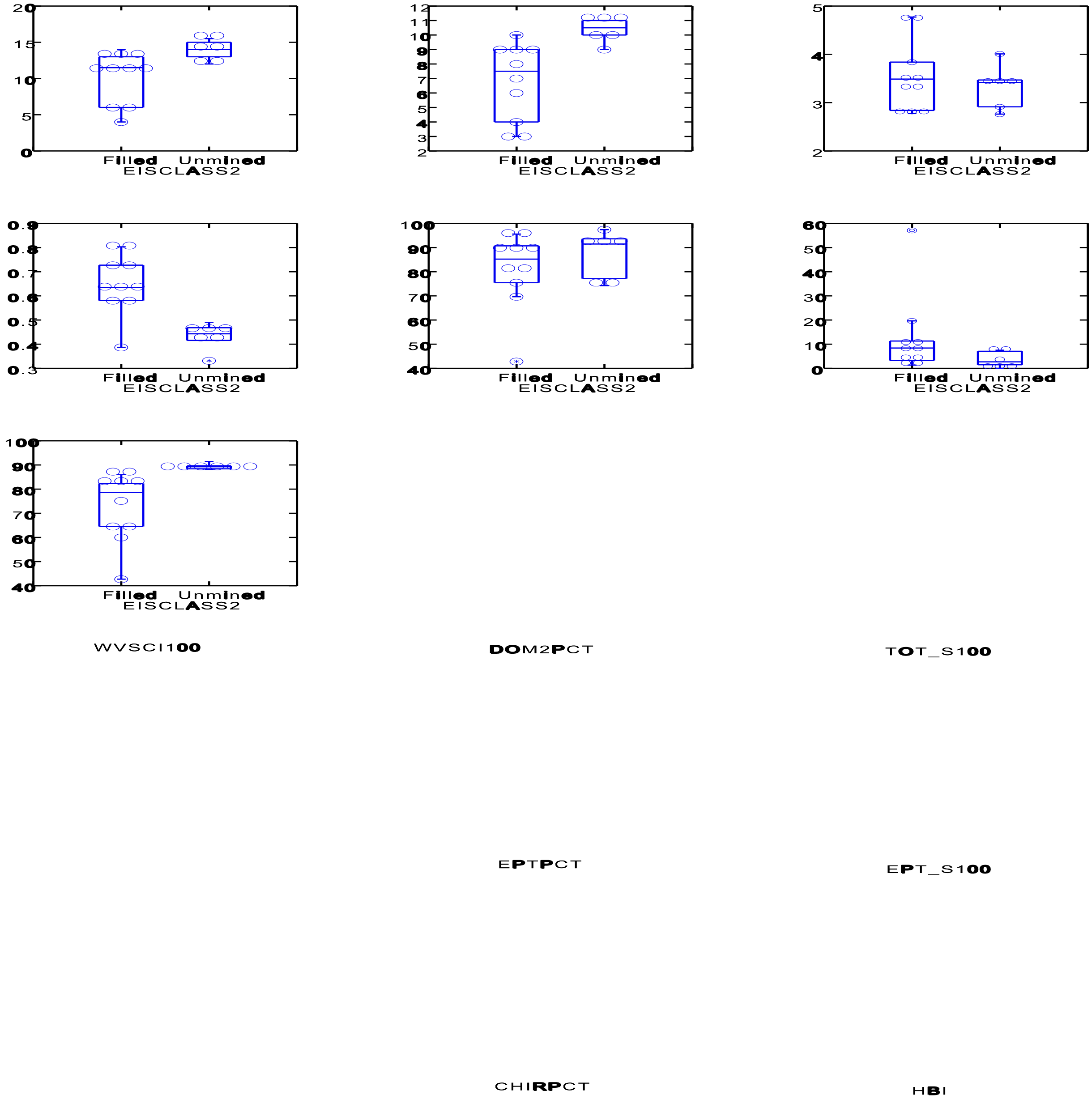


Figure C-6. Box plots of the WVSCI and its component metrics versus the EIS class for the winter 2001 season. Circles represent site scores.

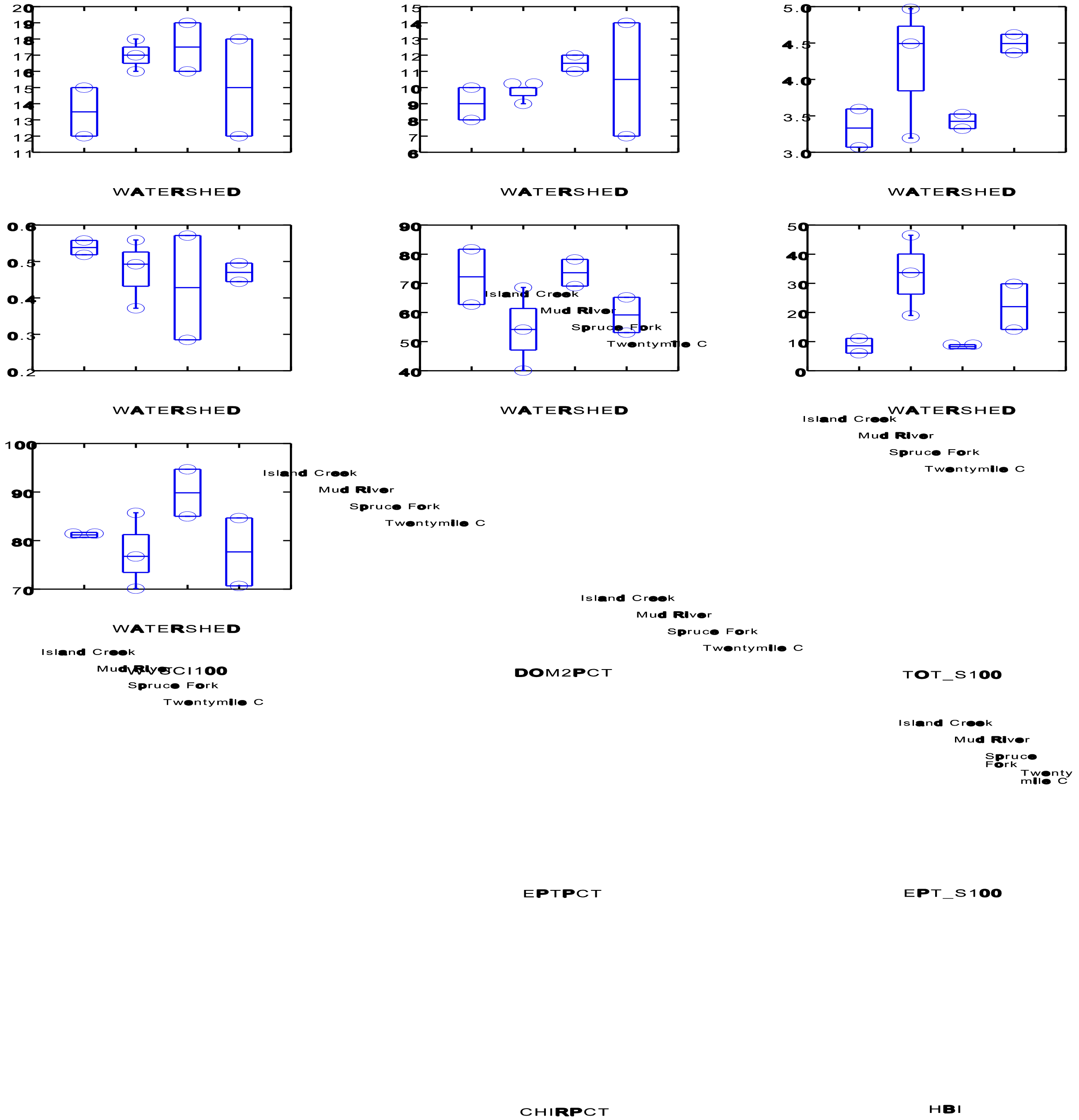


Figure C-7. Box plots of the WVSCI and its component metrics versus watershed for unmined sites in the spring 1999 season.

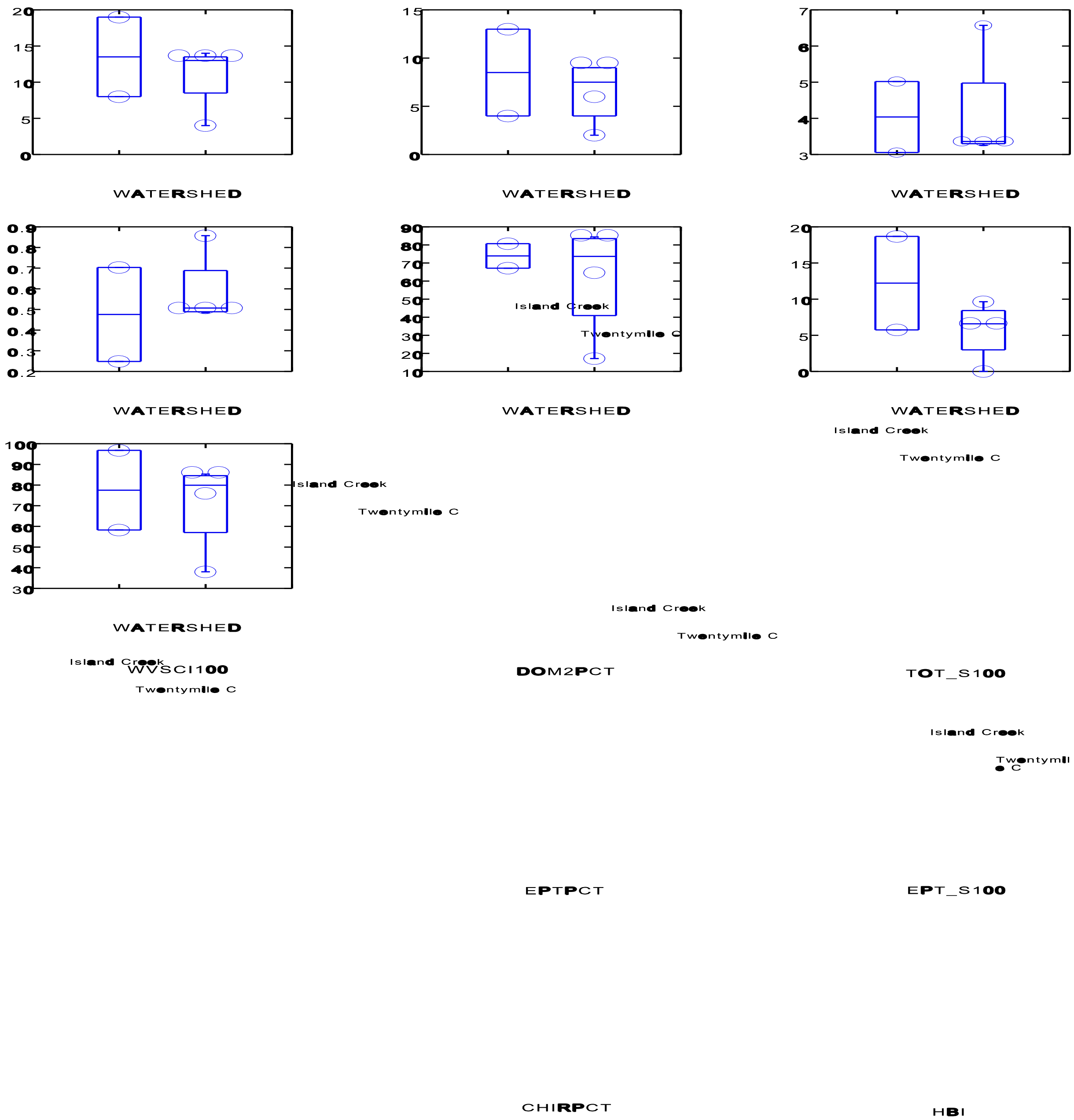


Figure C-8. Box plots of the WVSCI and its component metrics versus watershed for unmined sites in the autumn 1999 season.

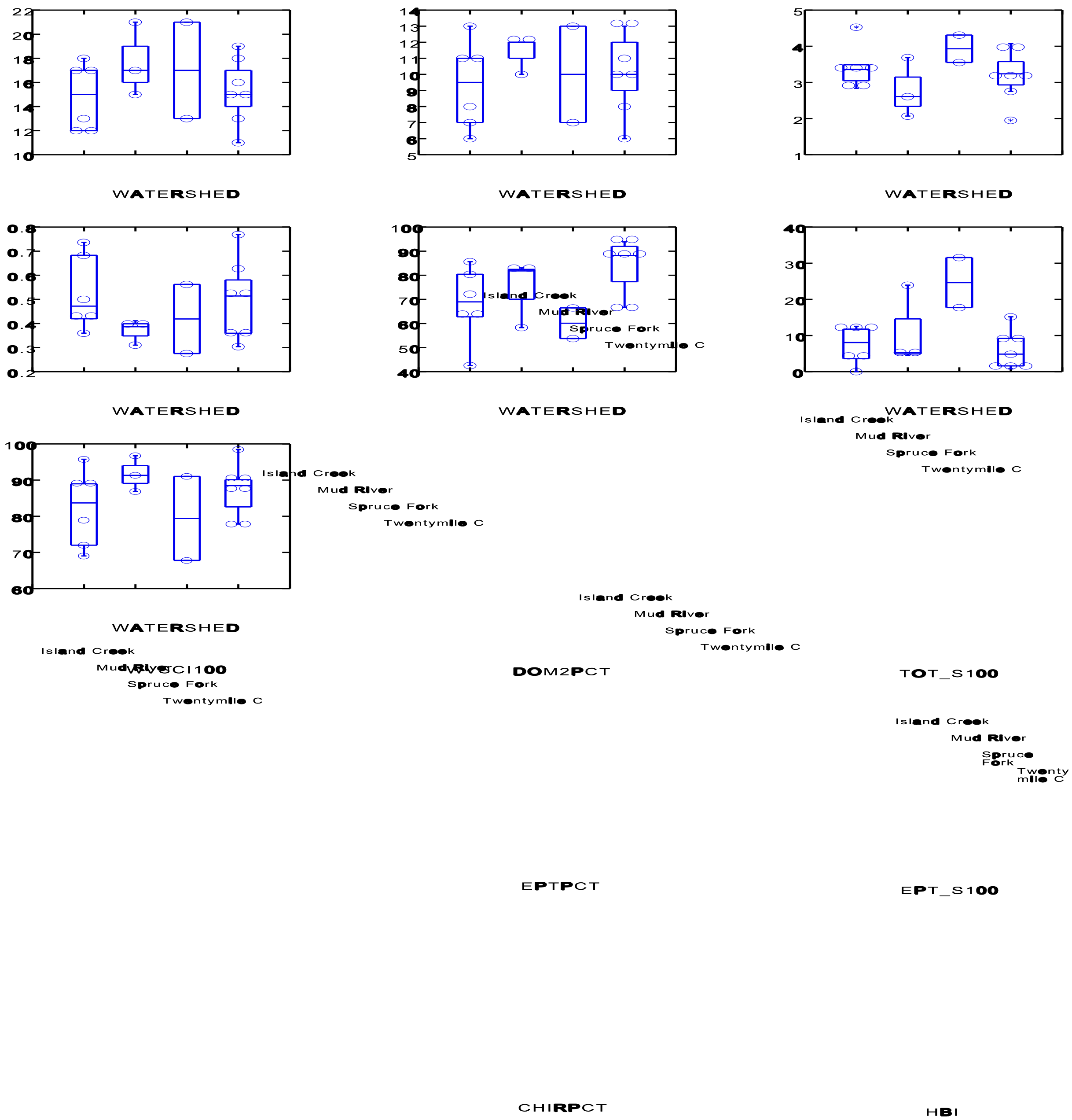


Figure C-9. Box plots of the WVSCI and its component metrics versus watershed for unmined sites in the winter 2000 season.

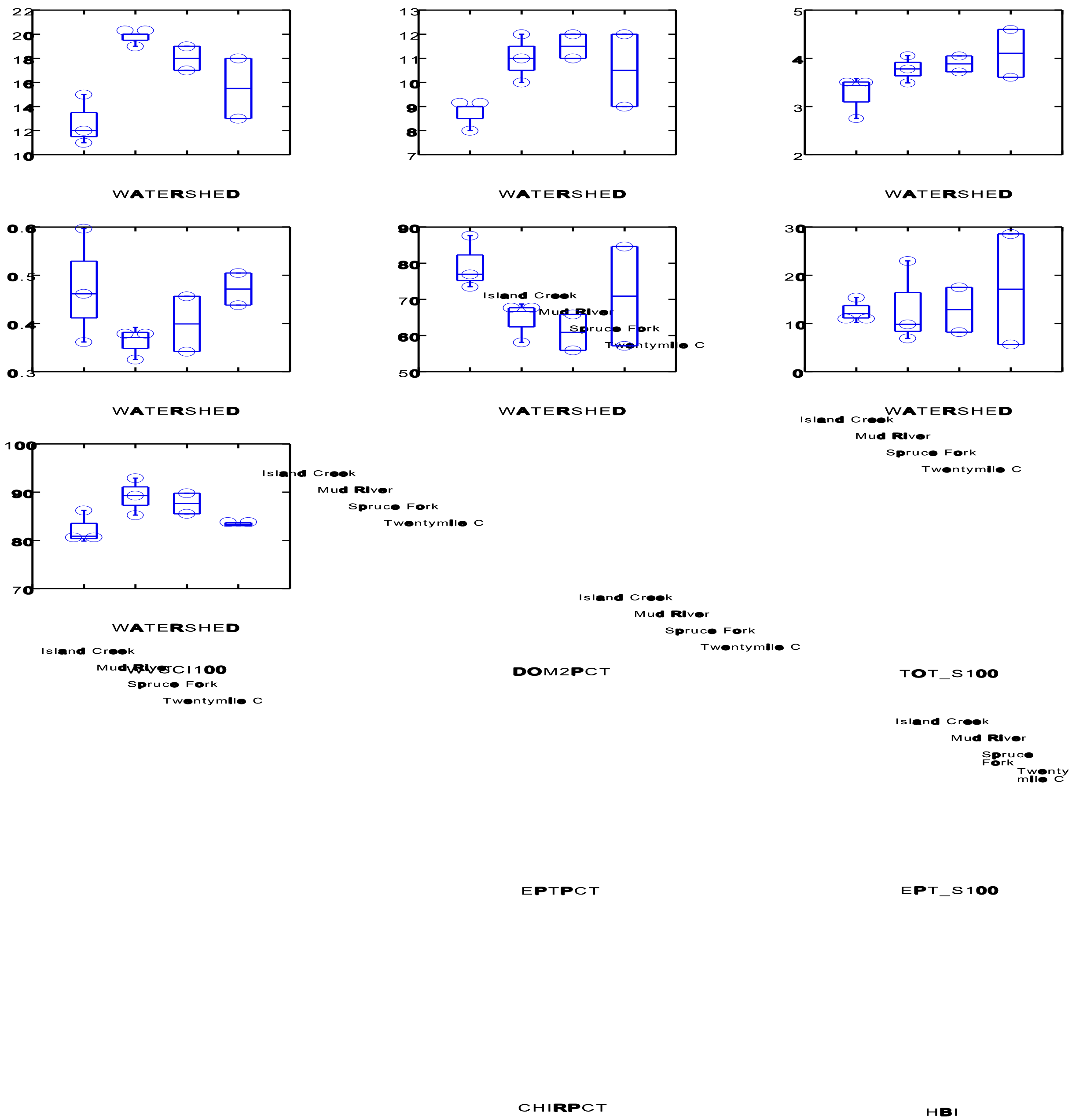


Figure C-10. Box plots of the WVSCI and its component metrics versus watershed for unmined sites in the spring 2000 season.

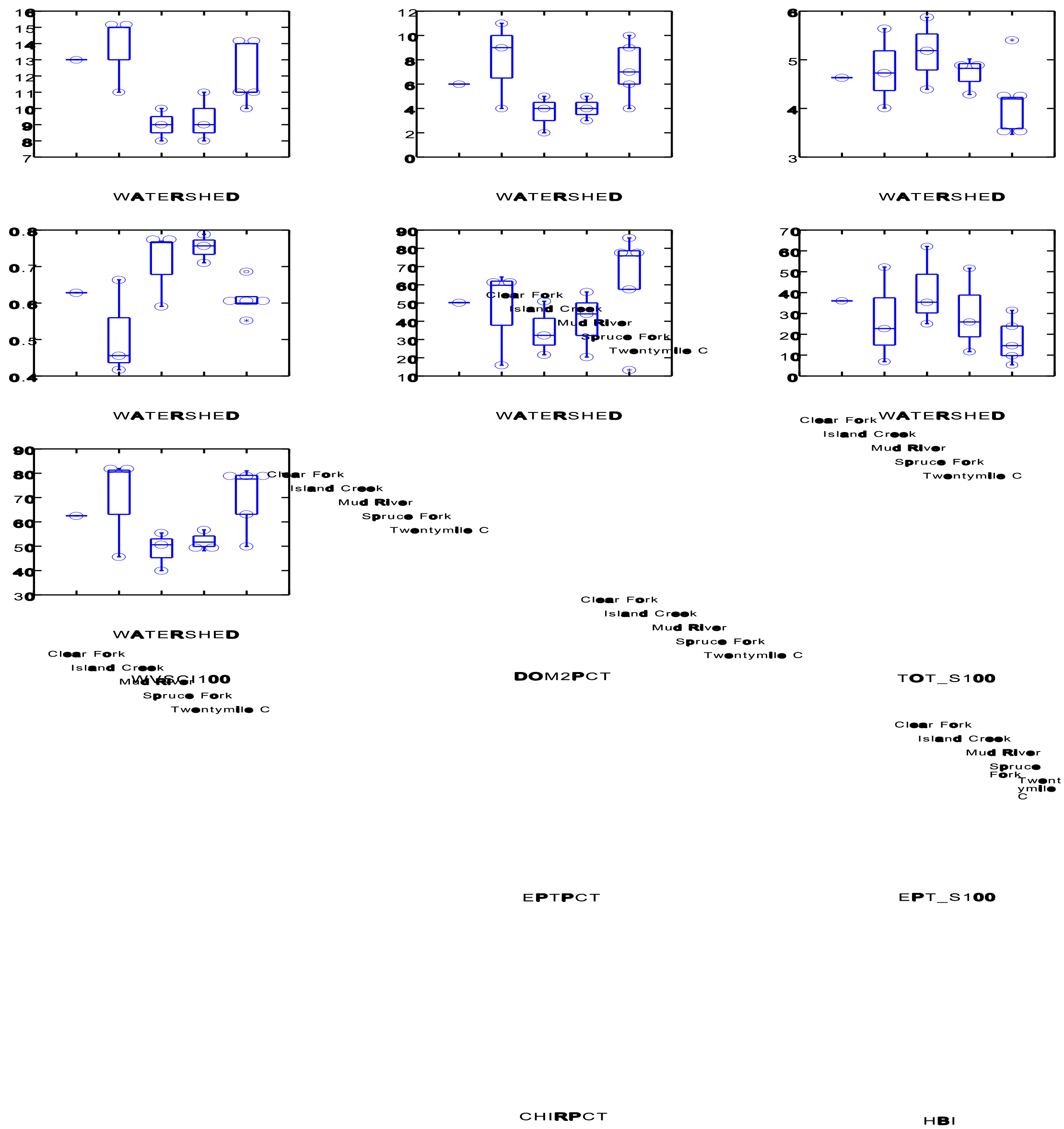


Figure C-11. Box plots of the WVSCI and its component metrics versus watershed for Filled sites in the spring 1999 season. Circles represent site scores.

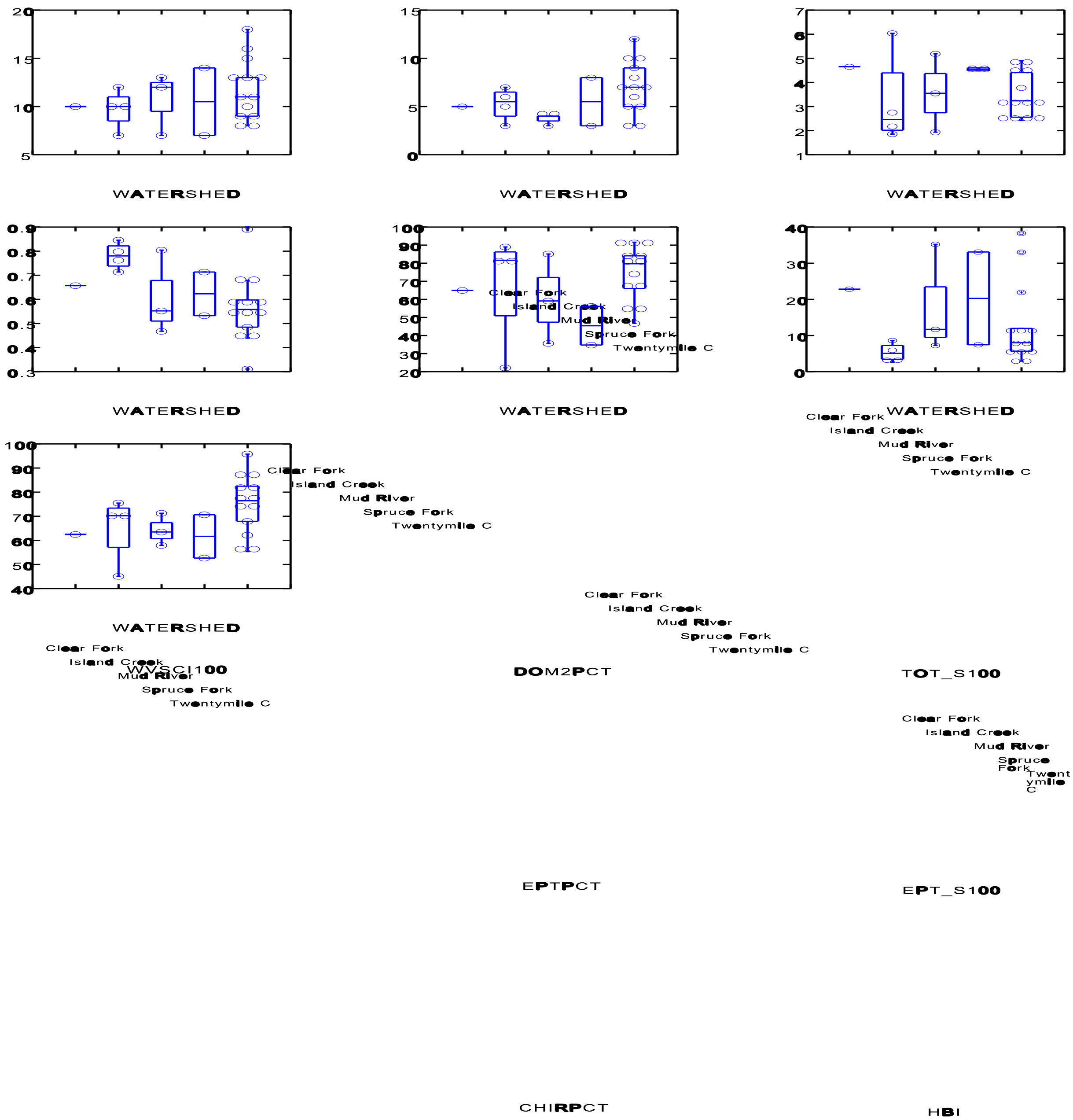


Figure C-12. Box plots of the WVSCI and its component metrics versus watershed for Filled sites in the autumn 1999 season. Circles represent site scores.

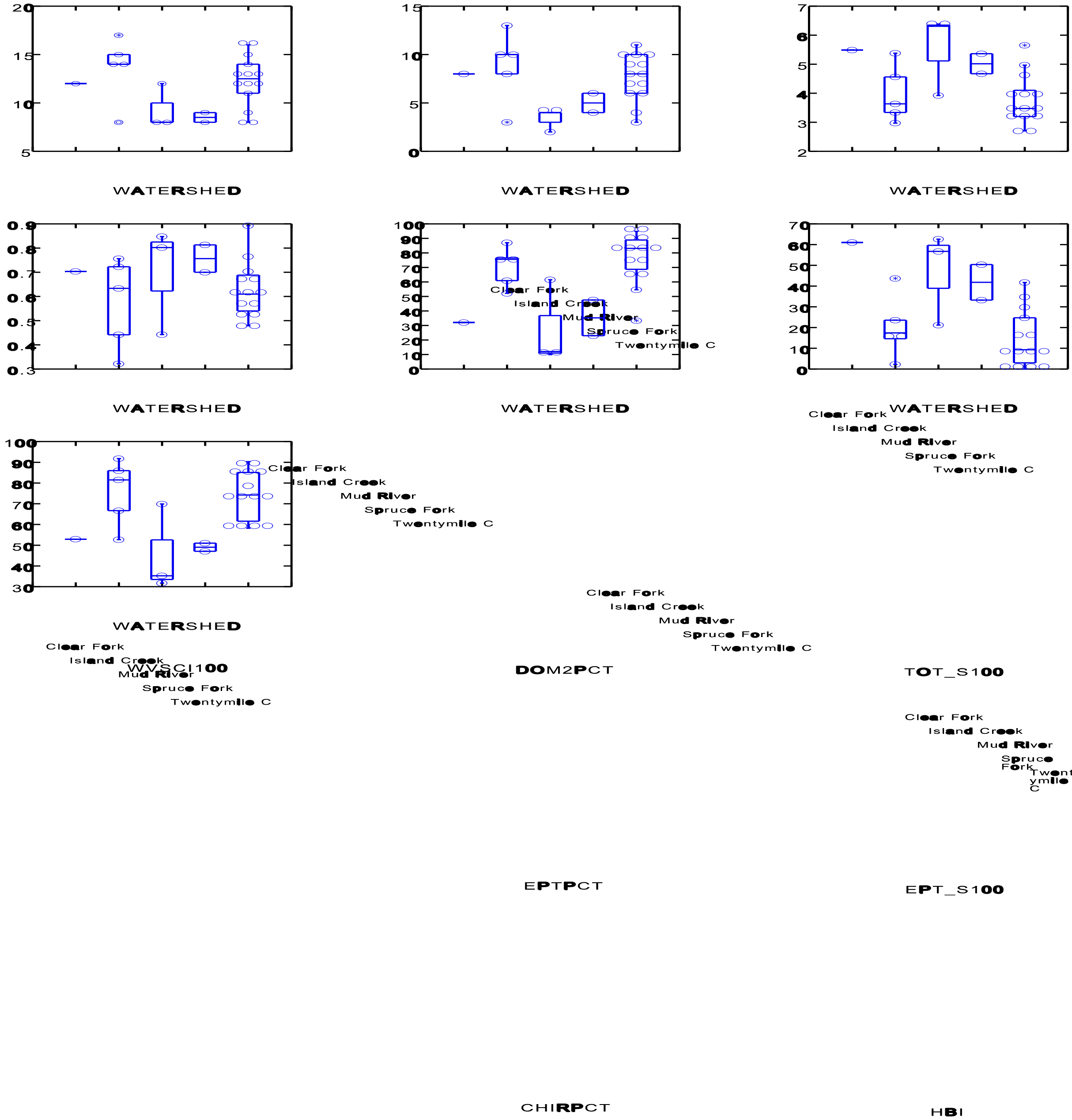


Figure C-13. Box plots of the WVSCI and its component metrics versus watershed for Filled sites in the winter 2000 season. Circles represent site scores.

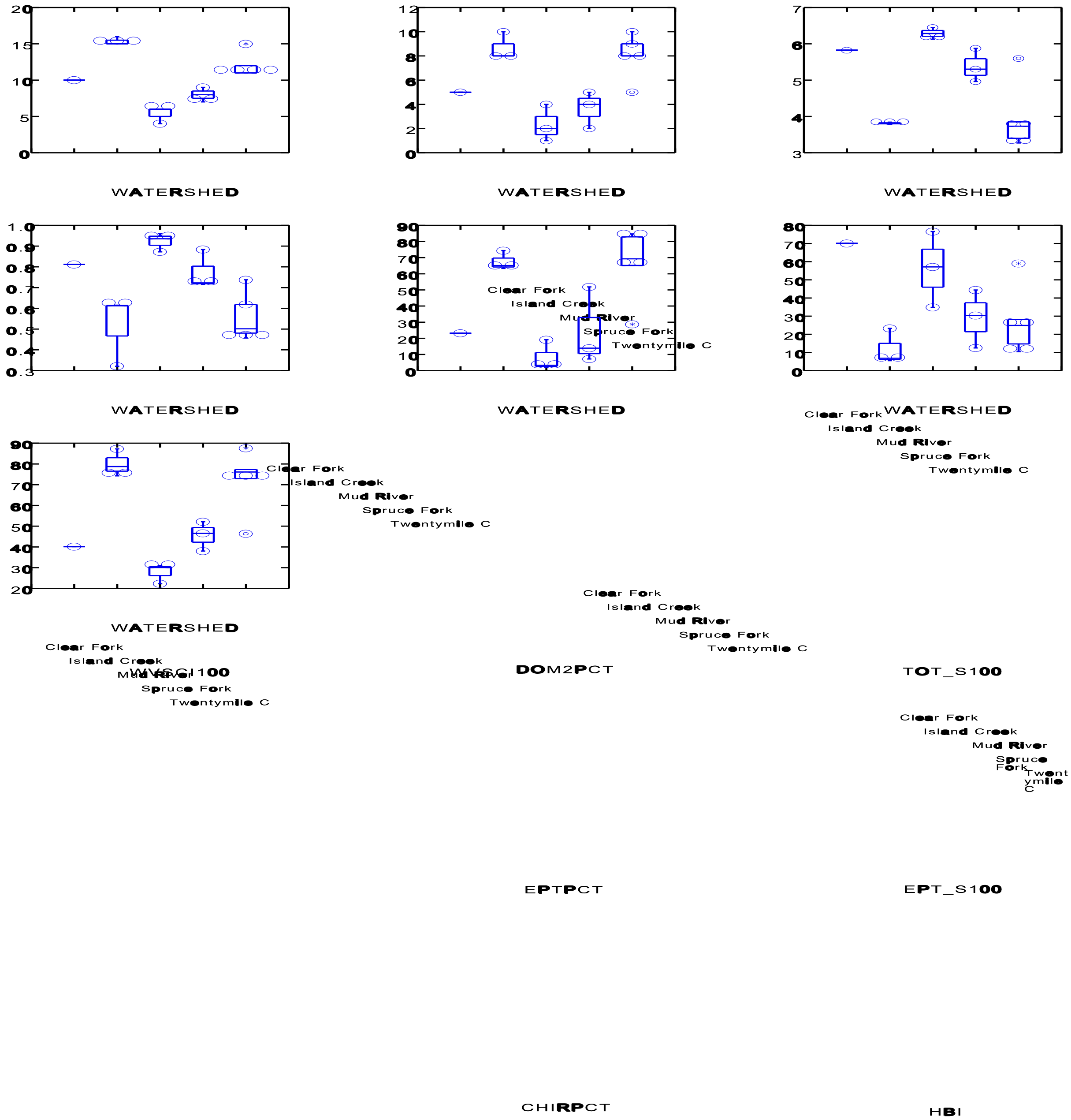


Figure C-14. Box plots of the WVSCI and its component metrics versus watershed for Filled sites in the spring 2000 season. Circles represent site scores.

APPENDIX D

SCATTER PLOTS OF THE WVSCI VERSUS KEY WATER QUALITY PARAMETERS

Figure D-1. The WVSCI, rarefied to 100 organisms, versus water quality parameters. Dashed line represents best fit line using linear regression.

Figure D-1. Continued.

Figure D-1. Continued.

Figure D-1. Continued.

APPENDIX E
STANDARDIZATION OF DATA AND METRIC CALCULATIONS

Standardization and Statistical Treatment of MTM/VF Fish Data

Fish Sample Collection Methods

Fish communities, like benthic communities, respond to changes in their environment. Some fish species are less tolerant of degraded conditions; as stream health decreases, they will either swim away or perish. Other species are more tolerant of degraded conditions, and will dominate the fish community as stream health declines.

Fish are collected using a backpack electrofisher. In electrofishing a sample area, or "reach", is selected so that a natural barrier (or a block net, in the absence of a natural barrier) prevents fish from swimming away upstream or downstream. An electrical current is then discharged into the water. Stunned fish float to the surface and are captured by a net, and held in buckets filled with stream water. The fish are identified, counted and often measured and/or weighed. Three passes are made with the electrofisher to collect all the fish in the selected stream reach. After the three passes are complete and the fishes have recovered, they are released back to their original habitat. Some fish may be retained as voucher specimens. The data collected from the three passes are composited into a single sample for the purposes of the MTM-VF project.

Pennsylvania State University (PSU) conducted fish sampling for USEPA. PSU collected fish from 58 sites located on first through fifth order streams in West Virginia. Fish were also sampled by REIC, Potesta, and BMI, following the same protocols. The only exceptions were five samples taken by REIC that were made with a pram electrofisher. In a pram unit, the electrofishing unit is floated on a tote barge rather than carried in a backpack. Otherwise, the pram samples followed the same protocols.

The Mid-Atlantic Highland IBI

The Mid-Atlantic Highland Index of Biotic Integrity, or IBI, (McCormick et al. 2001), provides a framework for assessing the health of the fish community, which, like the WV SCI, indicates the overall health of a stream. The IBI was developed and calibrated for the Mid-Atlantic Highlands using samples from several Mid-Atlantic states, including West Virginia. The IBI is a compilation of scores from nine metrics that are responsive to stress (Table E-1).

Table E-1. Metrics included in the Mid-Atlantic Highland IBI, with descriptions and expected response to increasing degrees of stress.

Metric	***Metric Description***	***Predicted Response to Stress***
Native Intolerant Taxa	**Number of indigenous taxa that are sensitive to pollution; adjusted for drainage area**	**Decrease**
Native Cyprinidae Taxa	**Number of indigenous taxa in the family Cyprinidae (carps and minnows); adjusted for drainage area**	**Decrease**
Native Benthic Invertivores	**Number of indigenous bottom dwelling taxa that consume invertebrates; adjusted for drainage area**	**Decrease**
Percent Cottidae	**Percent individuals of the family Cottidae (sculpins)**	**Decrease**
Percent Gravel Spawners	**Percent individuals that require clean gravel for reproductive success**	**Decrease**
Percent Piscivore/Invertivores	**Percent individuals that consume fish or invertebrates**	**Decrease**
Percent Macro Omnivore	**Percent individuals that are large and omnivorous**	**Increase**
Percent Tolerant	**Percent individuals that are tolerant of pollution**	**Increase**
Percent Exotic	**Percent individuals that are not indigenous**	**Increase**

Watershed Standardization

In nature, larger watersheds are naturally more diverse than smaller watersheds. Not surprisingly, this was found to be true in the MTM-VF project. To ensure that differences among fish communities are due to differences in stream health and not from the natural effect of watershed size, three richness metrics were standardized to a 100km^2 watershed.
This standardization applies only to the three richness metrics; percentage metrics are not affected by watershed size and required no adjustment before scoring.

The regression equations used in the watershed standardization were developed by McCormick et al. 2001. They studied the relationship between watershed size and fish community richness in minimally stressed sites, and derived equations that predict the number of taxa that would be expected in a healthy stream of a given watershed size. The equations were not published in the original 2001 paper, but were obtained from McCormick in a personal communication.

First, the predicted numbers of taxa were calculated using the regression equations. Then residual differences were calculated:

Residual difference = Actual number in sample – Predicted number

Finally, an adjustment factor was added to the residual difference (see Table E-2), depending on the richness metric.

Table E-2. Regression equations and adjustment factors for standardizing richness metrics to a 100 km2 watershed. (McCormick, personal communication)

Richness Metric	***Regression Equation***	***Adjustment Factor***
Native Intolerant Taxa	**predicted = 0.440071 + 0.515214 * Log_{10} (Drainage Area [km^2])**	**1.470**
Native Cyprinidae Taxa	**predicted = 0.306788 + 2.990011 * Log_{10} (Drainage Area [km^2])**	**6.287**
Native Benthic Invertivores	**predicted = 0.037392 + 2.620796 * Log_{10} (Drainage Area [km^2])**	**5.279**

Metric Scoring and IBI Calculation

After the necessary watershed adjustments had been made, metric scores were applied to the adjusted richness metrics and the raw percentage metrics. The scoring regime was originally derived from the distribution characteristics of the large Mid-Atlantic Highlands data set upon which the IBI was calibrated (McCormick et al. 2001).

Some metrics decrease in value with increasing stress, such as the richness metrics. For example, the number of intolerant species (those sensitive to poor water quality) decreases as stream health declines. Each of the metrics that decreases in value with increasing stress was given a score ranging from 0 – 10 points. Zero points were given if the adjusted value was less than the 5^{th} percentile of McCormick's non-reference sites; 10 points were given if the adjusted value was greater than the 50^{th} percentile of McCormick's high quality reference sites. Intermediate metric values, those between 0 and 10, were interpolated between the two end points.

Other metrics increase in value with increasing stress, such as the percent of tolerant fish species. As stream health declines, only the tolerant species thrive. Metrics that increase in value with increasing stress are also given a score ranging from 0 to 10. A score of 0 points is given to values greater than the 90^{th} percentile of McCormick's non-reference sites. A score of 10 points are given to values less than the 50th percentile of McCormick's moderately restrictive reference sites. Intermediate metric values were scored by interpolation between 0 and 10.

After all nine metrics have been scored, they are summed. Nine metrics scoring a possible 10 points each equals a possible maximum of 90 points; to convert to a more easily understood 100-point scale, the raw sum score is multiplied by 1.11. The Mid-Atlantic Highlands IBI is this resulting number, on a scale of 0-100 (Table E-3).

Table E-3. Mid-Atlantic Highland IBI: Metric scoring formulas. Richness metrics were adjusted for drainage area before calculating scores.

Metric	***Scoring formulas (X=metric value)***
Native Intolerant Taxa (Adjusted for watershed)	**If X>1.51, then 10. If X<0.12, then 0. Else 10*X/1.39**
Native Cyprinidae Taxa (Adjusted for watershed)	**If X>6.24, then 10. If X<1.54, then 0. Else 10*X/4.70**
Native Benthic Invertivore Taxa (adjusted for watershed)	**If X>5.34, then 10. If X<1.27, then 0. Else 10*X/4.07**
Percent Cottidae	**If X>7, then 10. Else 10*X/7**
Percent Gravel Spawners	**If X>72, then 10. If X<21.5, then 0. Else 10*X/50.5**
Percent Piscivore/Invertivores	**If X>9, then 10. Else 10*X/9**
Percent Macro Omnivore	**If X>16, then 0. If X<0.2, then 10. Else 10*(16-X)/15.8**
Percent Tolerant	**If X>97, then 0. If X<28, then 10. Else 10*(97-X)/69**
Percent Exotic	**If X>24, then 0. If X<0.2, then 10. Else 10*(24-X)/23.8**
SUM of all 9 metric scores	**Raw Score**
Mid-Atlantic Highland IBI score (0-100 range)	**Raw Score x 1.11**

Standardization and Metric Calculations of Benthic Data

Benthic Sample Collection Methods

What do we know about healthy Appalachian streams? There are many species of organisms that live in streams (insects, crustaceans, mussels, worms), and in general, healthy streams have a greater variety of animals than unhealthy streams. Three groups of insects in particular, the mayflies, stoneflies, and caddisflies, are sensitive to pollution and degradation and tend to disappear as a stream's water quality decreases. Other insect groups are more tolerant to pollution, and tend to increase as a percentage of the total benthic (bottom-dwelling) communities in unhealthy streams. In order to determine whether a stream is healthy or unhealthy, we must obtain a representative estimate of the variety and identity of species in the stream.

How do biologists sample stream communities to get a representative and precise estimate of the number of species? First, we must know where the organisms live in the stream. An Appalachian stream bottom is not a uniform habitat: there are large rocks, cobble, gravel, patches of sand, and tree trunks in the streambed. Each of these is a microhabitat and attracts species specialized to live in the microhabitat. For example, some species live on the tops of rocks, in the current, to catch food particles as they drift by. Some species crawl around in protected areas on the underside of rocks; some cling to fallen tree trunks or branches; yet others live in gravel or sand. Clearly, if we sample many microhabitats, we will find more species than if we sample only one. In order to characterize the stream section, we need to sample a large enough area to ensure that we have sampled most of the microhabitats present.

How do we "measure" the biological effects of human activities, such as mining, on stream ecosystems? What is the unit of the stream that we characterize? Typically, we wish to know the effects on a wide variety of organisms throughout the stream. However, sampling everything is expensive and potentially destructive. Selecting a single, common habitat that is an indicator of stream condition is analogous to a physician measuring fever with an oral thermometer at a single place (the mouth). Therefore, biologists selectively sample riffles, which are prevalent in Appalachian streams, and are preferred habitat for many sensitive species. When we sample a riffle, we wish to characterize the entire riffle, not just an individual rock or patch of sand, and sampling must represent the microhabitats present. By taking several samples, even with a relatively small sampling device such as a Surber Sampler, we can ensure that enough microhabitats have been sampled to obtain an accurate estimate of diversity in the stream.

Sampling Gear

Sampling also depends on the gear and equipment that biologists use to capture organisms. Small samplers and nets can be easily and economically handled by one or two persons; larger sampling equipment requires larger crews. In the MTM-VF project, the sampling protocol calls for 6 Surber samples (0.09 square meter each, for 0.56 square meter total from each site), or 4 D-frame samples (0.25 square meter each, for 1 square meter from each site). If the Surber or D-frame grabs are spread out throughout the riffle (preferably in a random manner), then they will adequately represent most of the microhabitats present, and total diversity of the riffle can be characterized.

Standardization of data

Many agencies were involved in the collection of data for the Mountain Top Mining Environmental Impact Statement. Not all organizations used the same field sampling methods, and during the two-year investigation, some organizations changed their sampling methods. In order to "compare apples to apples," it is necessary to standardize the data, so that duplicate samples taken using different methods will yield the same results after standardization.

We begin here with a description of the sampling methods used, a general discussion of sampling, analysis of a set of paired samples using two methods, and finally the specific steps used to standardize the samples from the different organizations.

MTM/VF Benthic Sampling Methods

The two methods used in the MTM/VF study, which we term the "D-frame method" and the "Surber method," differ in sampling gear and in the treatment of the collected material. The methods are compared below.

Equipment: A D-frame net is a framed net, in the shape of a "D", which is attached to a pole.

Procedure: The field biologist positions the D-frame net on the stream bottom, then dislodges the stream bottom directly upstream to collect the stream-bottom material, including sticks and leaves, and all the benthic organisms. The net is 0.5 meter wide, and $0.25 m^2$ area of streambed is sampled with each deployment. In the MTM/VF study, the net was deployed 4 times at each site, for a total area of $1.0\ m^2$.

Compositing: All the collected materials were composited into a single sample.

Subsampling: Samples collected in the D-frame method are often quite large, and two organizations "subsampled" to reduce laboratory processing costs. In subsampling, the samples are split using a sample splitter (grid), and a subsample consisting of 1/8th (or, in the case of samples with few organisms, 1/4th or 1/2) of the original material was analyzed. All organisms in the subsample were identified and counted.

Equipment: A Surber sampler is a square frame, covering 1 square foot ($0.093 m^2$) of stream bottom.

Procedure: The Surber is placed horizontally on cobble substrate in shallow stream riffles. A vertical section of the frame has the net attached and captures the dislodged organisms from the sampling area.
In the MTM/VF study, the Surber sampler was deployed 3 to 6 times at each site, for a total area sampled of 3 to 6 square feet (0.28 to $0.56 m^2$).

Compositing: The materials collected were not composited, but were maintained as discrete sample replicates.

Subsampling: The materials collected in each of the Surbers were not subsampled. All organisms were identified and counted.

The D-frame sampler was most consistently used by participants. EPA and Potesta used only D-frame sampling; BMI used only D-frame sampling in the first two sets of samples, and afterwards used both Surber and D-frame samplers. REIC collected both Surber and D-frame samples throughout the study. The various methods used by the organizations participating in the MTM/VF study are summarized in Table E-4.

Table E-4. A comparison of each organization's methods of collecting and compositing samples, and laboratory subsampling protocols.

Organization	***Sample Method***	***Compositing***	***Subsampling***
USEPA	4 times 1/4m^2 D-frame net	Composited samples	1/8 of original sample. If abundance was low, the laboratory subsampled to 1/4 or ½ of the original sample, or did not subsample at all.

REIC (Twelvepole Creek)	3 times Surber and 4 times 1/4m^2 D-frame net	All Surber samples were analyzed separately (no compositing). Composited samples.	The D-frame samples were subsampled to 1/4 of original sample if necessary. All 7 samples were combined for reporting, representing approximately 1.3 m^2 of stream bottom.
Potesta (Twenty Mile Creek)	4 times 1/4 m^2 D-frame net.	Composited samples	Not subsampled; counted to completion.
BMI (Twenty Mile Creek)	Fall 1999 and Spring 2000: 4 times 1/4 m^2 D-frame net. Fall 2000, 6 times Surber, and four times 1/4 m^2 D-frame net. Spring 2001, 4 times Surber and four times 1/4m^2 D-frame sample**.**	Composited samples. Surber samples kept separate. D-frame samples were composited. Surber samples kept separate. D-frame samples were composited.	Not subsampled; counted to completion. Not subsampled; counted to completion. Not subsampled; counted to completion.
BMI (Island Creek):	Fall 1999 and Spring 2000, four times 1/4 m^2 D-frame net, Fall 2000, 4 times Surber, kept separate, and four times 1/4 m^2 D-frame net, composited. Spring 2001: No data.	Composited samples. Surber samples were kept separate. D-frame samples were composited.	Not subsampled; counted to completion. Not subsampled; counted to completion.

Treatment of Sampler Data

How do we treat data from the samplers? A common method is to take the average of measures from several (4 or 6) samplers. The problem with this approach is that we know that each sampler, individually, underestimates species richness of the stream site; thus the average of underestimates will also be an underestimate (see Table E-5). In addition to species (or family) richness, a measure important in the West Virginia Stream Condition Index, and in many other similar condition indexes, is the degree to which a community is dominated by the most abundant species found. In degraded streams, communities are often dominated by one or a few species tolerant of poor habitat or poor water quality. In a healthy stream, dominance over the entire community is low. However, a single microhabitat, such as a large rock, is likely to by dominated by one or two species adapted to that microhabitat. A different species will be dominant in a sand habitat. The entire riffle is diverse and has low dominance when we consider several microhabitats. Thus, if we calculate the average dominance over several small sampling devices, such as Surbers, we overestimate community dominance. Each Surber sample may be highly dominated by a different species, yet the overall community may not dominated by any of those species. This is shown with data from one of the sites (Table E-5): average richness of Surbers is lower than richness of the composited Surbers (representing the entire riffle). Average dominance of the Surbers is higher than the composited sample. By averaging, this site appears to be in poorer condition than it really is, especially if compared to West Virginia's Stream Condition Index.

Standardizing Sampling Effort

Sampling effort is a combination of the total riffle area sampled, the heterogeneity of the stream bottom sampled, and the number of organisms identified. As previously discussed, a composited sample that consists of several smaller samples from throughout the riffle area will adequately characterize the abundances and relative abundances of most of the common species at a site. It will not, however, necessarily characterize all of the rare species at a site (those making up less than about 2% of the total community). Sampling to collect all rare species is prohibitively expensive and destructive of the riffle. But we must consider the effects of rare species since they contribute to diversity and richness measures in proportion to sampling effort. For example, the D-frame net, which covers 1 m^2, (10.8 square feet) will capture more rare species than 4 or 6 Surber samplers, which cover only 0.37 m^2 (4 square feet) and 0.56 m^2 (6 square feet) respectively. By the same token, subsampling, or counting only a portion of the total sample, also undercounts rare species.

Fortunately, it is relatively easy to standardize sampling effort among different sampling methods so that the bias is removed. Standardization is done by adjusting taxa counts to expected values for subsamples smaller than an original sample, using the following binomial probabilities for the capture of each taxon (Hurlbert 1971; Vinson and Hawkins 1996).

= The expected number of species in a sample of *n* individuals selected at random from a collection containing N individuals, S species, and N_i individuals in the ith species.

Taxa counts (number of species or families) can only be adjusted down to the level of the smallest sampling effort in the data set; it is not possible to estimate upwards (and effectively "make up" data). In the MTM/VF data, benthic samples were standardized to 200 individuals, which is the standard WV SCI practice, and to 100 individuals, to accommodate those samples that contained less than 200 organisms. Individual taxa are not removed from a sample in the standardization process; only the taxa counts are standardized. Estimates of abundance per area and relative abundance are unaffected by sampling effort, and are not adjusted.

Table E-5. Six Surber replicates from site MT-52 (Island Creek), Fall 1999. The dominant family for each Surber is in bold, outlined with a heavy line. The subdominant family is outlined with a light line. Either Taeniopterygidae or Nemouridae are dominant in each Surber, but they tend not to co-occur in the same Surber. Metrics are shown at the bottom.

Comparison of Paired Samples

We analyzed matched data collected by EPA and Potesta Associates at 21 sites in Island Creek, Mud River, and Spruce Fork over 3 sampling periods from Summer 1999 to Winter 2000. EPA sampled using its D-frame method described above, and Potesta used the 6-Surber method described above. EPA also took an additional 21 samples using both methods, at 10 different sites. Sample crews visited sites simultaneously. The objective of this analysis was to determine the comparability of samples collected using two different methods. If sample pairs collected in both ways, at the same site and time, show no bias relative to each other, then the two sampling methods would be considered comparable and valid for assessments.

Figure E-1 shows the cumulative number of families in 6 Surbers at 5 representative sites, showing that each successive Surber captures new families not captured by the previous Surbers.

Figure E-1. Cumulative number of families identified in successive Surber samplers from 5 MTM sites.

If we consider the number of organisms captured per unit area of the stream bottom, the 2 methods are unbiased. Figure E-2 compares the individuals per square meter as estimated using Surbers, with individuals per square meter estimated using D-frame samples. The diagonal dotted line represents exact agreement (1:1). While there is scatter about the line, there is no bias above or below the line. Note that Potesta and EPA samples overlap and are unbiased with respect to each other.

Figure E-2. Total number of individuals from 6 Surber samplers and from EPA D-frame samples. Each point represents a comparison of Surber and D-frame results from the same site at the same time. The vertical axis is the Surber results, and the horizontal axis is the D-frame results. The dotted line is the 1:1 slope of exact agreement between methods. Potesta Surber results are shown with solid diamonds; EPA Surbers with open triangles. All D-frame samples were from EPA.

As explained above, calculating the average number of families from 6 Surbers underestimates richness, since each individual Surber underestimates richness. This is shown graphically in Figure E-3. The average number of families from the Surbers is shown on the vertical axis, and the total families from the D-frame on the horizontal axis. Nearly all the points lie below the 1:1 line. The average bias is approximately 5 families. If we plot the total, cumulative families using Surbers against those using D-frames (Figure E-4), then the D-frames underestimate relative to the Surbers by about 5 taxa, because the D-frames were subsampled to 1/8th the total sample volume. However, if both Surber and D-frame samples are composited and standardized to a constant number of organisms (200), then there is no bias in the family richness (Figure E-5). Note also in Figure 5 that the scatter of points about the 1:1 line is much smaller than for the unstandardized data shown in Figures 3 and 4, and that both Potesta and EPA Surber are unbiased to each other (note 2 symbols in figure).

Figure E-3. Number of families per site, averaged over 6 Surbers (vertical), against total numbers from D-frame samples. See Figure 2 caption.

Figure E-4. Total families per site, from composite of 6 Surbers (cumulative), compared to EPA D-frame results. As in Figures 2 and 3.

Figure E-5. Number of taxa in standardized Surber samples (vertical) compared to standardized D-frame samples (horizontal). As in Figures 2-4.

The West Virginia Stream Condition Index (WV SCI) is calculated from 6 metric scores. When the index was developed, the scoring formulas were calibrated to a 200 organism sample (Gerritsen et al. 2000). If samples were larger than 200 organisms, they were standardized before the scoring formulas were applied.

Summary: Standardization of Benthic Data

In summary, the data collected by the participants differed in sampling, subsampling and reporting methods. Despite the differences, any one of these sampling, subsampling, and reporting methods is unbiased with respect to the types of organisms collected (all used the same mesh size), the density of organisms (numbers per unit area), and the relative abundances (percent of community). The only bias is that of the number of families (taxa richness) as affected by sampling effort. Sampling effort is a combination of the total area sampled, the heterogeneity of the stream bottom sampled, and the size of the subsample. Since all participants used the same field methods for the D-frame samples, 4 D-frames in the field, use of the D-frame data standardizes the field sampling effort. However, EPA subsampled to $1/8^{th}$ of the total material (with some exceptions noted in the data); REIC to $1/4^{th}$ the total material (with some exceptions); and all others counted the entire sample. Therefore, taxa richness was standardized to be equivalent to a subsample of $1/8^{th}$ the total, original material. Unfortunately, REIC data was reported as combined D-frame and Surber samples and could not be standardized for both sampling effort and subsampling in the laboratory.

Metric Calculations for Benthic Data

The West Virginia Stream Condition Index (WV SCI) rates a site using an average of six standard indices, or metrics, each of which assesses a different aspect of stream health.

The WV SCI metrics include:

- Total Taxa – a count of the total number of families found in the sample. This is a measure of diversity, or richness, and is expected to increase with stream health.
- Number of EPT Taxa – a count of the number of families belonging to the Orders Ephemeroptera (mayflies), Plecoptera (stoneflies), or Tricoptera (caddisflies) Members of these three insect orders tend to be sensitive to pollution. The number tends to increase with stream health.
- Percent EPTs (Number of EPT families / Total number of Families) - this measures the contribution of the pollution-sensitive EPT families to the total benthic macroinvertebrate community. It tends to increase with stream health.
- Percent Chironomidae – the percentage of pollution-tolerant midge (gnat) larvae in the family Chironomidae tends to decrease in healthy streams and increase in streams that are subjected to organic pollution.
- Percent 2 dominant families - a measure of diversity of the stream benthic community. This metric tends to decrease with stream health.
- Hilsenhoff Biotic Index (HBI). The HBI assigns a pollution tolerance value to each family (more pollution-tolerant taxa receive a higher tolerance value). Tolerance values were found in the literature (Hilsenhoff 1987, Barbour et al. 1999) or were assigned by EPA biologists from Wheeling, WV or Cincinnati, OH. The HBI is then calculated by averaging the tolerance values of each specimen in a sample. The HBI tends to increase as water quality decreases

Several taxa were excluded from the analysis because they inhabit terrestrial, marginal, or surface
areas of the stream. The excluded taxa included Aranae, Arachnida, Collembola, and Cossidae.

After all the benthic data had been migrated to EDAS, and after all the data had been collapsed to the Family level, the six WV SCI metrics were calculated from composited enumerations, or counts.

Metric Scoring and Index Calculation

As discussed previously, richness metrics are affected by sampling effort, and were therefore standardized to a 100 or 200 organism subsample before scoring. Other WV SCI metrics are independent of sampling effort and did not require standardization.
Each of the metrics was then scored on a scale of 0 to 100 using scoring formulae derived

for 100 and 200 organism subsamples (Table E-6). The WV SCI was calculated as an average of the six metric scores.

Table E-6. WV SCI: Metric scoring formulas. The richness metrics have two scoring formulas each, depending on the standardized sample size (100 or 200 organisms). The scoring formulas are from unpublished analyses for 100 organism richness metrics and Gerritsen et al. (2000) for 200 organism richness metrics and other metrics.

etrics that decrease with stress	***Scoring formulas (X=metric value)***
Total taxa	**ore$_{100}$ = 100 $\times$ (X/18), Score$_{200}$ = 100 $\times$ (X/21)**
EPT taxa	**ore$_{100}$ = 100 $\times$ (X/12), Score$_{200}$ = 100 $\times$ (X/13)**
% EPT	**ore = 100 $\times$ (X/91.9)**
that increase with stress	
%Chironomidae	**ore = 100 $\times$ [(100-X)/(100-0.98)]**
% 2 dominant	**ore = 100 $\times$ [(100-X)/(100-36.0)]**
HBI	**ore = 100 $\times$ [(10-X)/(10-2.9)]**

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Ecological Assessment of Streams in the Coal Mining Region of West Virginia Using Data Collected by the U.S. EPA and Environmental Consulting Firms

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Prepared by:

Florence Fulk and Bradley Autrey
U.S. Environmental Protection Agency
National Exposure Research Laboratory
Cincinnati, Ohio

John Hutchens
Coastal Carolina University
Conway, South Carolina

Jeroen Gerritsen, June Burton, Catherine Cresswell, and Ben Jessup
Tetra Tech, Inc.
Owings Mills, Maryland

U.S. Environmental Protection Agency
National Exposure Research Laboratory
26 W. Martin Luther King Drive
Cincinnati, Oh 45268

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EXECUTIVE SUMMARY

INTRODUCTION

Recently, the Mountaintop Mining (MTM) and Valley Fill (VF) operations in the Appalachian Coal Region have increased. In these operations, the tops of mountains are removed, coal materials are mined and the excess materials are deposited into adjacent valleys and stream corridors. The increased number of MTM/VF operations in this region has made it necessary for regulatory agencies to examine the relevant regulations, policies, procedures and guidance needed to ensure that the potential individual and cumulative impacts are considered. This necessity has resulted in the preparation of an Environmental Impact Statement (EIS) concerning the MTM/VF activities in West Virginia. The U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers, U.S. Office of Surface Mining, and U.S. Fish and Wildlife Service, in cooperation with the West Virginia Department of Environmental Protection, are working to prepare the EIS. The purpose of the EIS is to establish an information foundation for the development of policies, guidance and coordinated agency decision-making processes to minimize, to the greatest practicable extent, the adverse environmental effects to the waters, fish and wildlife resources in the U.S. from MTM operations, and to other environmental resources that could be affected by the size and location of fill material in VF sites. Furthermore, the EIS's purpose is to determine the proposed action, and develop and evaluate a range of reasonable alternatives to the proposed action.

The U.S. EPA's Region 3 initiated an aquatic impacts study to support the EIS. From the spring 1999 through the winter 2000, U.S. EPA Region 3 personnel facilitated collection of water chemistry, habitat, macroinvertebrate and fish data from streams within the MTM/VF Region. In addition, data were also collected by three environmental consulting firms, representing four coal mining companies. The National Exposure Research Laboratory (NERL) of the U.S. EPA's Office of Research and Development assembled a database of U.S. EPA and environmental consulting firm data collected from the MTM/VF Region. Using this combined data set, NERL analyzed fish and macroinvertebrate data independently to address two study objectives: 1) determine if the biological condition of streams in areas with MTM/VF operations is degraded relative to the condition of streams in unmined areas and 2) determine if there are additive biological impacts to streams where multiple valley fills are located. The results of these analyses, regarding the aquatic impacts of MTM/VF operations, are provided in this report for inclusion in the overall EIS.

ANALYTICAL APPROACH AND RESULTS

Fish Data Analyses and Results

The Mid-Atlantic Highlands Index of Biotic Integrity (IBI), was used in the analyses of the fish data. This index is made up of scores from multiple metrics that are responsive to stress. Each of the sites sampled was placed into one of six EIS classes (i.e., Unmined, Filled, Mined, Filled/Residential, Mined/Residential, Additive). Due to inadequate sample size, the Mined/Residential class was removed from analyses. The Additive class was analyzed separately because it was made up of sites that were potentially influenced by multiple sources of stress.

The objective of the IBI analyses were to examine and compare EIS classes to determine if they are associated with the biological condition of streams. The distributions of IBI scores showed that the Filled and Mined classes had lower overall IBI scores than the other EIS classes. The Filled/Residential class had higher IBI scores than the Filled or Mined classes. The combined Filled/Residential class and the Unmined class had median scores that were similar to regional reference sites. Unmined and regional reference sites were primarily in the "fair" range and a majority of the Filled/Residential sites fell within the "good" range.

A standard Analysis of Variance (ANOVA) was used to test for differences among EIS classes and the Least Square (LS) Means procedure using Dunnett's adjustment for multiple comparisons tested whether the Filled, Filled/Residential, and Mined EIS classes were significantly different ($p < 0.01$) from the Unmined class. The ANOVA showed that there were significant differences among EIS classes. The LS Means test showed that the IBI scores from Filled and Mined sites were significantly lower than the IBI scores from Unmined sites, and the IBI scores from Filled/ Residential sites were significantly higher than the IBI scores from Unmined sites. Of the nine metrics in the IBI, only the Number of Minnow Species and the Number of Benthic Invertivore Species were significantly different in the Unmined class. Therefore, it was determined that the primary causes of reduced IBI scores in Filled and Mined sites were the reductions in these two metrics relative to the Unmined sites.

It was found that Filled, Mined, and Filled/Residential sites in watersheds with areas greater than 10 km^2 had "fair" to "good" IBI scores, while Filled and Mined sites in watersheds with areas less than 10 km^2 often had "poor" IBI scores. Of the 14 sites Filled and Mined) in watersheds with areas greater than 10 km^2, four were rated "fair" and ten were rated "good" or better. Of the 17 sites (Filled and Mined) in watersheds with areas less than 10 km^2, only three were rated "fair" and 14 were rated "poor". The effects of fills were statistically stronger in watersheds with areas less than 10 km^2. Filled sites had IBI scores that were an average of 14 points lower than Unmined sites. It is possible that the larger watersheds act to buffer the effects of stress.

Additive sites were considered to be subject to multiple, and possibly cumulative, sources, and were not included in the analysis of the EIS classes reported above. From the additive analysis, it was determined that the Twelvepole Creek Watershed, in which the land use was mixed residential and mining, had "fair" IBI scores in most samples, and there are no apparent additive effects of the land uses in the downstream reaches of the watershed. Also, Twentymile Creek, which has only mining-related land uses, may experience impacts from the Peachorchard tributary. The IBI scores appear to decrease immediately downstream of the confluence of the two creeks, whereas above the confluence, IBI scores in the Twentymile Creek are higher than in the Peachorchard Creek. Peachorchard Creek may contribute contaminants or sediments to Twentymile Creek, causing degradation of the Twentymile IBI scores downstream of Peachorchard Creek.

The correlations between IBI scores and potential stressors detectable in water were examined. Zinc, sodium, nickel, chromium, sulfate, and total dissolved solids were associated with reduced IBI scores. However, these correlations do not imply causal relationships between the water quality parameters and fish community condition.

Macroinvertebrate Data Analyses and Results

The benthic macroinvertebrate data were analyzed for statistical differences among EIS classes. Macroinvertebrate data were described using the WVSCI and its component metrics. The richness metrics and the WVSCI were rarefied to 100 organisms to adjust for sampling effort. Four EIS classes (i.e.; Unmined, Filled, Mined, and Filled/Residential) were compared using one-way ANOVAs. Significant differences among EIS classes were followed by the Least Square (LS) Means procedure using Dunnett's adjustment for multiple comparisons to test whether the Filled, Filled/Residential, and Mined EIS classes were significantly different ($p < 0.01$) from the Unmined class. Comparisons were made for each of the sampling seasons where there were sufficient numbers of samples.

The results of the macroinvertebrate analyses showed significant differences among EIS classes for the WVSCI and some of its component metrics in all seasons except autumn 2000. Differences in the WVSCI were primarily due to lower Total Taxa, especially for mayflies, stoneflies, and caddisflies, in the Filled and Filled/Residential EIS classes. Sites in the Filled/Residential EIS class usually scored the worst of all EIS classes across all seasons.

Using the mean values for water chemistry parameters at each site, the relationships between WVSCI scores and water quality were determined. The strongest of these relationships were negative correlations between the WVSCI and measures of individual and combined ions. The WVSCI was also negatively correlated with the concentrations of Beryllium, Selenium, and Zinc.

Multiple sites on the mainstem of Twentymile Creek were identified as Additive sites and were included in an analysis to evaluate impacts of increased mining activities in the watershed across seasons and from upstream to downstream of the Twentymile Creek. Sites were sampled during four seasons. Pearson correlations between cumulative river kilometer and the WVSCI and it's component metrics were calculated. The number of metrics that showed significant correlations with distance along the mainstem increased across seasons. The WVSCI was significantly correlated with cumulative river kilometer in Winter 2000, Autumn 2000 and Winter 2001. For Winter 2001, a linear regression of the WVSCI with cumulative river kilometer indicated that the WVSCI decreased approximately one point upstream to downstream for every river kilometer.

MAJOR FINDINGS AND SIGNIFICANCE

Fish Data Findings and Significance

It was determined that IBI scores were significantly reduced at Filled sites compared to Unmined sites by an average of 10 points, indicating that fish communities were degraded below VFs. The IBI scores were similarly reduced at sites receiving drainage from historic mining or contour mining (i.e., Mined sites) compared to Unmined sites. Nearly all Filled and Mined sites with catchment areas smaller than 10 km^2 had "poor" IBI scores. At these sites, IBI scores from Filled sites were an average of 14 points lower than the IBI scores from Unmined sites. Filled and Mined sites with catchment areas larger than 10 km^2 had "fair" or "good" IBI scores. Most of the Filled/Residential sites were in these larger watersheds and tended to have "fair" or "good" IBI scores.

It was also determined that the Twelvepole Creek Watershed, which had a mix of residential and mining land uses, had "fair" IBI scores in most samples; there were no apparent additive effects of the land uses in the downstream reaches of the watershed. Twentymile Creek, which had only mining-related land uses, had "good" IBI scores upstream of its confluence with Peachorchard Creek, and "fair" and "poor" scores for several miles downstream of its confluence with Peachorchard Creek. Peachorchard Creek had "poor" IBI scores, and may have contributed to the degradation of the Twentymile Creek's IBI scores downstream of their confluence.

Macroinvertebrate Data Findings and Significance

The macroinvertebrate analyses showed significant differences among EIS classes for the WVSCI and some of its metrics in all seasons except autumn 2000. Differences in the WVSCI were primarily due to lower Total Taxa and lower EPT Taxa in the Filled and Filled/Residential EIS classes. Sites in the Filled/Residential EIS class usually had the lowest scores of all EIS classes across all seasons. It was not determined why the Filled/Residential class scored worse than the Filled class alone. U.S. EPA (2001 Draft) found the highest concentrations of sodium in the Filled/Residential EIS class, which may have negatively impacted these sites compared to those in the Filled class.

When the results for Filled and Unmined sites alone were examined, significant differences were observed in all seasons except autumn 1999 and autumn 2000. The lack of differences between Unmined and Filled sites in autumn 1999 was due to a decrease in Total Taxa and EPT Taxa at Unmined sites relative to the summer 1999. These declines in taxa richness metrics in Unmined sites were likely the result of drought conditions. Despite the relatively drier conditions in Unmined sites during autumn 1999, WVSCI scores and EPT Taxa richness increased in later seasons to levels seen in the spring 1999, whereas values for Filled sites stayed relatively low.

In general, statistical differences between the Unmined and Filled EIS classes corresponded to ecological differences between classes based on mean WVSCI scores. Unmined sites scored “very good” in all seasons except autumn 1999 when the condition was scored as “good”. The conditions at Filled sites ranged from “fair” to “good”. However, Filled sites that scored “good” on average only represented conditions in the Twentymile Creek watershed in two seasons (i.e., autumn 2000 and winter 2001). These sites are not representative of the entire MTM/VF study area. On average, Filled sites had lower WVSCI scores than Unmined sites.

The consistently higher WVSCI scores and the Total Taxa in the Unmined sites relative to Filled sites across six seasons showed that Filled sites have lower biotic integrity than sites without VFs. Furthermore, reduced taxa richness in Filled sites is primarily the result of fewer pollution-sensitive EPT taxa. The lack of significant differences between these two EIS classes in autumn 1999 appears to be due to the effects of greatly reduced flow in Unmined sites during a severe drought. Continued sampling at Unmined and Filled sites would improve the understanding of whether MTM/VF activities are associated with seasonal variation in benthic macroinvertebrate metrics and base-flow hydrology.

Examination of the Additive sites from the mainstem of Twentymile Creek indicated that impacts to the benthic macroinvertebrate communities increased across seasons and upstream to downstream of Twentymile Creek. In the first sampling season one metric, Total Taxa, was negatively correlated with distance along the mainstem. The number of metrics showing a relationship with cumulative river mile increased across seasons, with four of the six metrics having significant correlations in the final sampling season, Winter 2001. Also in Winter of 2001, a regression of the WVSCI versus cumulative river kilometer estimates a decrease of approximately one point in the WVSCI for each river kilometer. Season and cumulative river kilometer in this dataset may be surrogates for increased mining activity in the watershed.

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1. INTRODUCTION

1.1. Background

Since the early 1990s, the nature and extent of coal mining operations in the Appalachian Region of the U.S. have changed. An increased number of large (> 1,200-ha) surface mines have been proposed and technology has allowed for the expanded role of Mountaintop Mining (MTM) and Valley Fill (VF) operations. In these operations, the tops of mountains are removed in order to make the underlying coal accessible (Figure 1-1). The excess materials from the mountaintop removals typically have been deposited into adjacent valleys and their stream corridors (Figure 1-2). These depositions cover perennial streams, wetlands and tracts of wildlife habitat. Given the increased number of mines and the increased scale of mining operations in the MTM/VF Region, it has become necessary for federal and state agencies to ensure that the relevant regulations, policies, procedures and guidance adequately consider the potential individual and cumulative impacts that may result from these projects (U.S. EPA 1999).

1.2. Environmental Impact Statement Development

The U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers (COE), U.S. Office of Surface Mining (OSM), and U.S. Fish and Wildlife Service (FWS), in cooperation with the West Virginia Department of Environmental Protection (DEP), are preparing an Environmental Impact Statement (EIS) concerning the MTM/VF activities in West Virginia. The purpose of developing the EIS is to facilitate the informed consideration of the development of policies, guidance and coordinated agency decision-making processes to minimize, to the greatest extent practicable, the adverse environmental effects to the waters, fish and wildlife resources in the U.S. from MTM operations, and to other environmental resources that could be affected by the size and location of fill material in VF sites (U.S. EPA 2001). Additionally, The EIS will determine the proposed action, and develop and evaluate a range of reasonable alternatives to the proposed action.

The goals of the EIS are to: (1) achieve the purposes stated above; (2) assess the mining practices currently being used in West Virginia; (3) assess the additive effects of MTM/VF operations; (4) clarify the alternatives to MTM; (5) make environmental evaluations of individual mining projects; (6) improve the capacity of mining operations, regulatory agencies, environmental groups and land owners to make informed decisions; and (7) design improved regulatory tools (U.S. EPA 2000). The major components of the EIS will include: human and

Figure 1-1. A MTM operation in West Virginia. The purpose of these operations are to remove mountaintops in order to make the underlying coal accessible.

Figure 1-2. A VF in operation. The excess materials from a MTM operation are being placed in this adjacent valley.

community impacts (i.e., quality of life, economic), terrestrial impacts (i.e., visuals, landscape, biota), aquatic impacts and miscellaneous impacts (i.e., blasting, mitigation, air quality).

1.3. Aquatic Impacts Portion of the EIS

The U.S. EPA's Region 3 initiated an aquatic impacts study to support the EIS. From the spring (i.e., April to June) 1999 through the winter (i.e., January to March) 2000, the U.S. EPA Region 3 collected data from streams within the MTM/VF Region. These data include water chemistry, habitat, and macroinvertebrates. With cooperation and guidance from the U.S. EPA Region 3, the Pennsylvania State University's (PSU's) School of Forest Resources collected fish data from streams in the MTM/VF Region. In addition to the data that were collected by the U.S. EPA Region 3 and PSU, data were also collected by three environmental consulting firms, representing four coal mining companies. These environmental consulting firms were Biological Monitoring, Incorporated (BMI); Potesta & Associates, Incorporated (POTESTA); and Research, Environmental, and Industrial Consultants, Incorporated (REIC).

Three reports which describe the data collected by the U.S. EPA Region 3 and PSU's School of Forest Resources were prepared. The first report summarized the condition of streams in the MTM/VF Region based on the macroinvertebrate data that were collected (Green et al. 2000 Draft). This report provided a descriptive analysis of the macroinvertebrate data. The second report described the fish populations in the MTM/VF Region based on the fish data collected by the PSU's School of Forest Resources (Stauffer and Ferreri 2000 Draft). This report used a fish index that was developed by the Ohio EPA for larger streams. The third report was a survey of the water quality of streams in the MTM/VF Region based on the water chemistry data collected by the U.S. EPA Region 3 (U.S. EPA 2002 Draft).

1.4. Scope and Objectives of This Report

In this document, the National Exposure Research Laboratory (NERL) of the U.S. EPA's Office of Research and Development (ORD) has assembled a database of Region 3, PSU and environmental consulting firm data collected from the MTM/VF Region. Using this combined data set, NERL analyzed fish and macroinvertebrate data separately to address the study's objectives. The results of these analyses will allow NERL to provide a report on the aquatic impacts of the MTM/VF operations for inclusion in the EIS.

The objectives of this document are to: 1) determine if the biological condition of streams in areas with MTM/VF operations is degraded relative to the condition of streams in unmined areas and 2) determine if there are additive biological impacts in streams where multiple VFs are located.

1.5. Biological Indices

One of the ways in which biological condition is assessed is through the use of biological indices. Biological indices allow stream communities to be compared by using their diversity, composition and functional organization. The use of biological indices is recommended by the Biological Criteria portion of the U.S. EPA's National Program Guidance for Surface Waters (U.S. EPA 1990). As of 1995, 42 states were using biological indices to assess impacts to streams (U.S. EPA 1996).

Two indices were identified as being appropriate for use with data collected from the MTM/VF Region. These were the Mid-Atlantic Highlands Index of Biotic Integrity (IBI) for fish (McCormick et al. 2001) and the West Virginia Stream Condition Index (WVSCI) for invertebrates (Gerritsen et al. 2000).

Due to the lack of a state developed fish index for West Virginia, an index created for use in the Mid-Atlantic Highlands was selected for evaluation of the fish data. The Mid-Atlantic Highlands IBI (McCormick et al. 2001) was developed using bioassessment data collected by the U.S. EPA from 309 wadeable streams from 1993 to 1996 in the Mid-Atlantic Highlands portion of the U.S. These data were collected using the U.S. EPA's Environmental Monitoring and Assessment Program (EMAP) protocols (Lazorchak et al. 1998). Site selection was randomly stratified. Fish were collected within reaches whose lengths were 40 times the wetted width of the stream with minimum and maximum reach lengths being 150 and 500 m, respectively. All fish collected for these bioassessments were identified to the species taxonomic level. An Analysis of Variance (ANOVA) showed that there were no differences between the ecoregions in which the data were collected. A subset of the data was used to develop the IBI and another subset was used to validate the IBI and its component metrics. Fifty-eight candidate metrics were evaluated. Of these, 13 were rejected because they did not demonstrate an adequate range, two were rejected because they had excessive signal-to-noise ratios, three were rejected because they were redundant with other metrics, one was rejected because it remained correlated with watershed area after it had been adjusted to compensate for area and 30 were rejected because they were not significantly correlated with anthropogenic impacts. The remaining nine metrics used in the IBI are described in Table 1-2 (McCormick et al. 2001). All metrics were scored on a continuous scale from 0 to 10. Three sets of reference condition criteria (i.e., least restrictive, moderately restrictive, most restrictive) were used to determine the threshold values for the metrics. For the metrics which decrease with perturbation (Table 1-1), a score of 0 was given if the value was less than the 5th percentile of the values from non-reference sites and a score of 10 was given if the value was greater than the 50th percentile of the values from reference sites defined by the most restrictive criteria. For the metrics which increase with perturbation (Table 1-1), a score of 0 was given if the value was greater than the 90th percentile of the values from non-reference sites and a score of 10 was given if the value was less than the 50th percentile of the values from reference sites defined by the moderately restrictive criteria. The IBI scores were scaled from 0 to 100 by summing the scores from the nine metrics and multiplying this sum by 1.11.

Table 1-1. The nine metrics in the Mid-Atlantic Highlands IBI, their definitions and their expected responses to perturbations.

Metric	Metric Description	Predicted Response to Stress
Native Intolerant Taxa	Number of indigenous taxa that are sensitive to pollution; adjusted for drainage area	Decrease
Native Cyprinidae Taxa	Number of indigenous taxa in the family Cyprinidae (carps and minnows); adjusted for drainage area	Decrease
Native Benthic Invertivores	Number of indigenous bottom dwelling taxa that consume invertebrates; adjusted for drainage area	Decrease
Percent Cottidae	Percent individuals of the family Cottidae (i.e., sculpins)	Decrease
Percent Gravel Spawners	Percent individuals that require clean gravel for reproductive success	Decrease
Percent Piscivore/Invertivores	Percent individuals that consume fish or invertebrates	Decrease
Percent Macro Omnivore	Percent individuals that are large and omnivorous	Increase
Percent Tolerant	Percent individuals that are tolerant of pollution	Increase
Percent Exotic	Percent individuals that are not indigenous	Increase

The WVSCI (Gerritsen et al. 2000) was developed using bioassessment data collected by the WVDEP from 720 sites in 1996 and 1997. These data were collected using the U.S. EPA's Rapid Bioassessment Protocols (RBP, Plafkin et al. 1989). From these bioassessments, 100 benthic macroinvertebrates were identified to the family taxonomic level from each sample. The information derived from the analyses of these data were used to establish appropriate site classifications for bioassessments, determine the seasonal differences among biological metrics, elucidate the appropriate metrics to be used in West Virginia and define the thresholds that indicate the degree of comparability of streams to a reference condition. The analyses of these data showed that there was no benefit to partitioning West Virginia into ecoregions for the purpose of bioassessment. The analyses also showed that variability in the data could be reduced by sampling only from late spring through early summer. Using water quality and habitat criteria, the reference and impaired sites were identified among the 720 sampled sites. Then, a suite of candidate metrics were evaluated based on their abilities to differentiate between reference and impaired sites, represent different aspects of the benthic macroinvertebrate community (i.e., composition, richness, tolerance), and minimize redundancy among individual component metrics. Based on these evaluations, it was determined that the metrics making up the WVSCI should be EPT taxa, Total taxa, % EPT, % Chironomidae, the Hilsenhoff Biotic Index (HBI) and % 2 Dominant taxa (Table 1-2). Next, the values for these metrics were calculated for all 720 sites and those values were standardized by converting them to a 0-to-100-point scale. The standardized scores for the six metrics were averaged for each site in order to obtain index scores. Data collected from West Virginia in 1998 were used to test the index. This analysis showed that the index was able to discriminate between reference and impaired sites (Gerritsen et al. 2000).

Table 1-2. The six metrics in the WVSCI, their definitions and their expected responses to perturbations.

Metric	Definition	Expected Response to Perturbation
EPT Taxa	The total number of EPT taxa.	Decrease
Total Taxa	The total number of taxa.	Decrease
% EPT	The percentage of the sample made up of EPT individuals.	Decrease
% Chironomidae	The percentage of the sample made up of Chironomidae individuals.	Increase
HBI	An index used to quantify an invertebrate assemblage's tolerance to organic pollution.	Increase
% 2 Dominant taxa	The percentage of the sample made up of the dominant two taxa in the sample.	Increase

2. METHODS AND MATERIALS

2.1. Data Collection

The U.S. EPA Region 3 collected benthic macroinvertebrate and habitat data from spring 1999 through spring 2000. These data were collected from 37 sites in five watersheds (i.e., Mud River, Spruce Fork, Clear Fork, Twentymile Creek, and Island Creek Watersheds) in the MTM/VF Region of West Virginia (Figure 2-1). Two sites were added to the study in spring 2000. These additions were a reference site not located near any mining activities and a supplementary site located near mining activities. Using these data, the U.S. EPA Region 3 developed a report (Green et al. 2000 Draft) which characterized the benthic macroinvertebrate assemblages in the MTM/VF Region of West Virginia.

The PSU's School of Forest Resources collected fish data in the MTM/VF Region of West Virginia and Kentucky. These data were collected from 58 sites in West Virginia and from 15 sites in Kentucky. The data collected from the Kentucky sites will not be used in this document. All of PSU's West Virginia sites were located in the same five watersheds from which the U.S. EPA Region 3 collected benthic macroinvertebrate, habitat and water quality data and most of these sites were located near the locations from which the U.S. EPA Region 3 collected these data. Data were collected in autumn 1999 and spring 2000. The results of this study were reported by Stauffer and Ferreri (2000 Draft).

The U.S. EPA Region 3 collected water quality data and water samples for chemical analyses from October 1999 through February 2001. These data were collected from the same 37 sites from which the U.S. EPA Region 3 collected benthic macroinvertebrate and habitat data. Using these data, the U.S. EPA Region 3 developed a report (U.S. EPA 2002 Draft) which characterized the water quality of streams in the MTM/VF Region of West Virginia.

The environmental consulting firm, BMI, collected water quality, water chemistry, habitat, benthic macroinvertebrate and fish data in the MTM/VF Region of West Virginia. These data were collected for Arch Coal, Incorporated from 37 sites in the Twentymile Creek Watershed and for Massey Energy Company from 11 sites in the Island Creek Watershed.

In addition, the environmental consulting firm, REIC, collected water quality, water chemistry, habitat, benthic macroinvertebrate and fish data in the MTM/VF Region of West Virginia. These data were collected for the Penn Coal Corporation from 18 sites in the Twelvepole Creek Watershed. Although the Twelvepole Creek Watershed is not among the

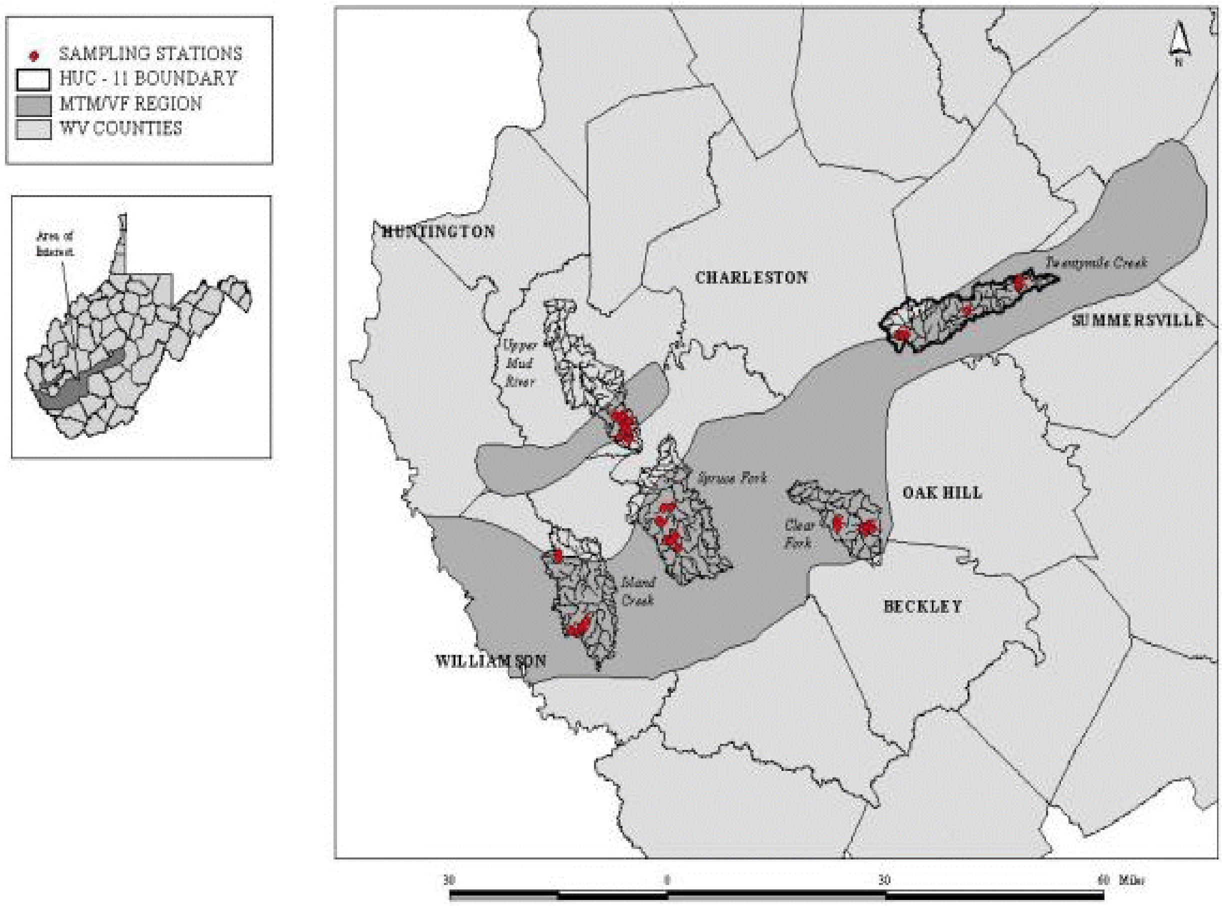


Figure 2-1. Study area for the aquatic impacts study of the MTM/VF Region of West Virginia.

watersheds from which the U.S. EPA Region 3 collected ecological data, some of these data will be considered in this report.

Finally, the environmental consulting firm, POTESTA, collected water quality, water chemistry, habitat, benthic macroinvertebrate, and fish data in the MTM/VF Region of West Virginia. These data were collected for the Fola Coal Company from ten sites in the Twentymile Creek Watershed (See Appendix E for a summary of benthic methods used by all groups).

2.2. Site Classes

Each of the sites sampled by the U.S. EPA Region 3, PSU or one of the participating environmental consulting firms was placed in one of six classes. These six classes were: 1)

Unmined, 2) Filled, 3) Mined, 4) Filled/Residential, 5) Mined/Residential and 6) Additive. The Unmined sites were located in areas where there had been no mining activities upstream. The Filled sites were located downstream of at least one VF. The Mined sites were located downstream of some mining activities but were not downstream of any VFs. The Filled/Residential sites were located downstream of at least one VF, and were also near residential areas. The Mined/Residential sites were located downstream of mining activity, and were also near residential areas. The additive sites were located on a mainstem of a watershed and were downstream of multiple VFs and VF-influenced streams.

2.3. Study Areas

2.3.1. Mud River Watershed

The headwaters of the Mud River are in Boone County, West Virginia, and flow northwest into Lincoln County, West Virginia. Although the headwaters of this watershed do not lie in the primary MTM/VF Region, there is a portion of the watershed that lies perpendicular to a five-mile strip of land in which mining activities are occurring. From the headwaters to the northwestern boundary of the primary MTM/VF Region, the watershed lies in the Cumberland Mountains of the Central Appalachian Plateau. The physiography is unglaciated, dissected hills and mountains with steep slopes and very narrow ridge tops and the geology is Pennsylvania sandstone, siltstone, shale, and coal of the Pottsville Group and Allegheny Formation (Woods et al. 1999). The primary land use is forest with extensive coal mining, logging, and gas wells. Some livestock farms and scattered towns exist in the wider valleys. Most of the low-density residential land use is concentrated in the narrow valleys (Green et al. 2000 Draft).

The U.S. EPA Region 3 sampled ten sites in the Mud River Watershed (Figure 2-2, Table 2-1). Brief descriptions of these sites are given below and more complete descriptions are given in Green et al. (2000 Draft). Site MT01 was established on the Mud River and the major disturbances at this site are a county road and residences. There also have been a few historical mining activities conducted upstream of site MT01. Site MT02 was established on Rush Patch Branch upstream of all residences and farms. While there is no history of mining in this sub-watershed, there is evidence of logging and gas well development. Site MT03 was established well above the mouth of Lukey Fork. Logging is the only known disturbance upstream of this site. Site MT13 was established on the Spring Branch of Ballard Fork. Other than historical logging activity, there is very little evidence of human disturbance associated with this site. Site MT14 was established on Ballard Fork. It is located downstream of eight VFs for which the mining permits were issued in 1985, 1988 and 1989. Site MT15 was established on Stanley Fork, located downstream of six VFs for which mining permits were issued in 1988, 1989, 1991, 1992 and 1995. Site MT24 was established in a sediment control structure on top of the mining operation located in the Stanley Fork sub-watershed. Site MT18 was established on Sugartree Branch. It was located downstream of two VFs for which the mining permits were

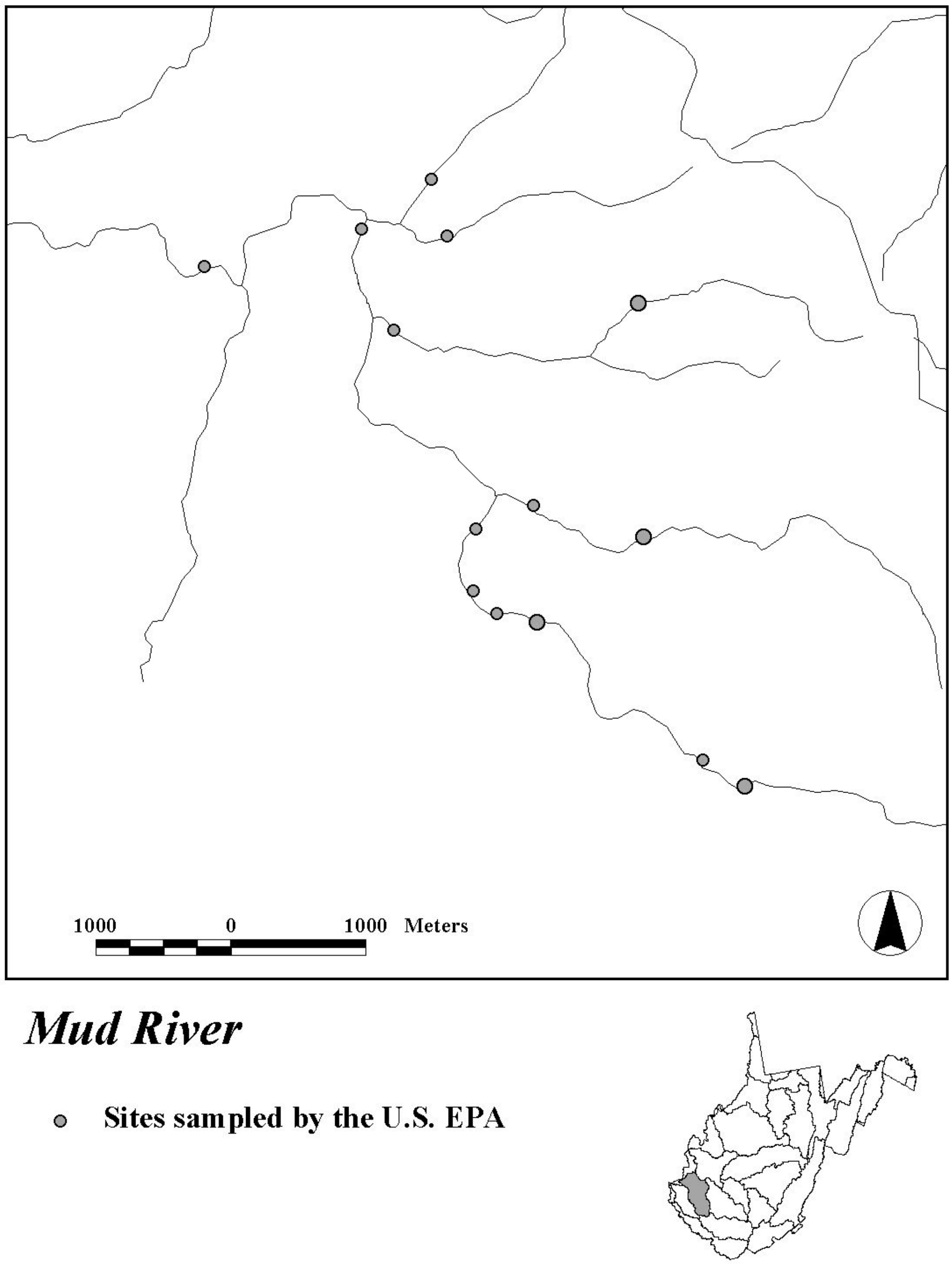


Figure 2-2. Sites sampled in the Mud River Watershed.

Table 2-1. Sites sampled in the Mud River Watershed.

Site ID/Organization	Stream Name	EIS Class
U.S. EPA Region 3		
MT01	Mud River	Mined/Residential
MT02	Rushpatch Branch	Unmined
MT03	Lukey Fork	Unmined
MT13	Spring Branch	Unmined
MT14	Ballard Fork	Filled
MT15	Stanley Fork	Filled
MT24	Unnamed Trib. to Stanley Fork	Sediment Control Structure
MT18	Sugartree Branch	Filled
MT23	Mud River	Filled/Residential
MT16	Unnamed Trib. to Sugartree Branch	Mined

issued in 1992 and 1995. Site MT23 was established on the Mud River downstream of mining activities. These activities include active and inactive surface mines and one active underground mine. In the spring of 2000, Site MT16 was established on an unnamed tributary to Sugartree Branch. This site was downstream of historical surface mining activities, but was not downstream of any VFs (Green et al. 2000 Draft).

2.3.2. Spruce Fork Watershed

The Spruce Fork Watershed drains portions of Boone and Logan Counties, West Virginia. The stream flows in a northerly direction to the town of Madison, West Virginia where it joins Pond Fork to form the Little Coal River. Approximately 85 to 90% of the watershed resides in the primary MTM region. Only the northwest corner of the watershed lies outside of this region. The entire watershed lies in the Cumberland Mountains sub-ecoregion (Woods et al. 1999). The watershed has been the location of surface and underground mining for many years, therefore, much of the watershed has been disturbed (Green et al. 2000 Draft).

The U.S. EPA Region 3 sampled eight sites in the Spruce Fork Watershed (Figure 2-3, Table 2-2). Brief descriptions of these sites are given below and more complete descriptions are given in Green et al. (2000 Draft). The U.S. EPA Region 3 Site MT39 was established on White Oak Branch and no mining activities existed in this area. Site MT40 was established on Spruce Fork. It is located downstream of seven known surface mining VFs and three VFs associated with refuse disposal. Site MT42 was established on Oldhouse Branch, located upstream of all residences and there is no known history of mining activities in this area. Site MT45 was

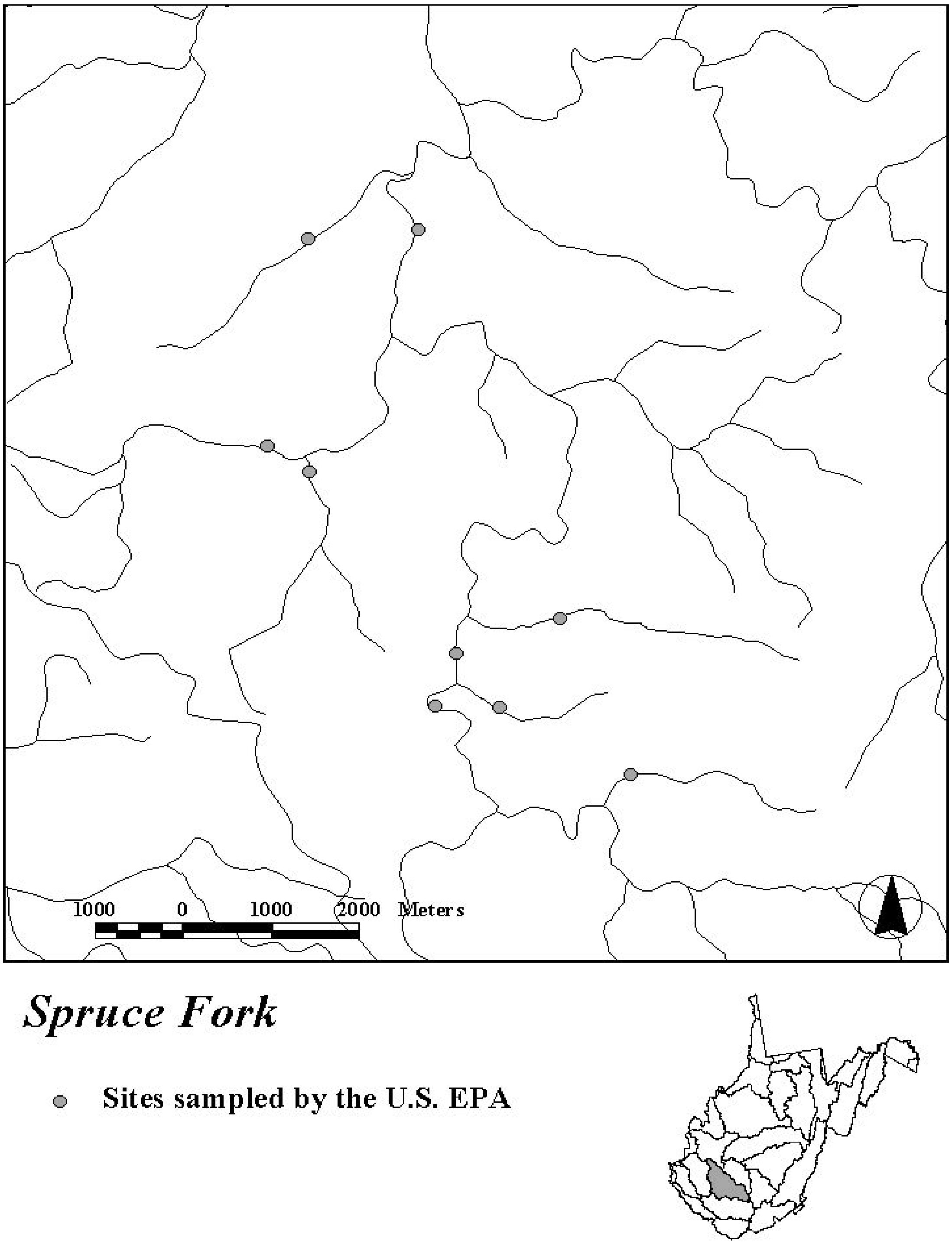


Figure 2-3. Sites sampled in the Spruce Fork Watershed.

Table 2-2. Sites sampled in the Spruce Fork Watershed.

Site ID/Organization	Stream Name	EIS Class
U.S. EPA Region 3		
MT39	White Oak Branch	Unmined
MT40	Spruce Fork	Filled/Residential
MT42	Oldhouse Branch	Unmined
MT45	Pigeonroost Branch	Mined
MT32	Beech Creek	Filled
MT34B	Left Fork	Filled
MT48	Spruce Fork	Filled/Residential
MT25B	Rockhouse Creek	Filled

established on Pigeonroost Branch. This site was located upstream of all residences but downstream of contour mining activities that occurred between 1987 and 1989. Site MT32 was established on Beech Creek. It was located downstream of five VFs and surface and underground mining activities. Site MT34B was established on the Left Fork of Beech Creek. It was located downstream of VFs and surface and underground mining activities. Site MT48 was established on Spruce Fork just upstream of Rockhouse Creek. There are known to be 22 VFs and several small communities upstream of this site. Site MT25B was established on Rockhouse Creek, located downstream of a sediment pond and a very large VF (Green et al. 2000 Draft).

2.3.3. Clear Fork Watershed

Clear Fork flows north toward its confluence with Marsh Fork where they form the Big Coal River near Whitesville, West Virginia. The entire watershed lies within Raleigh County, West Virginia within the Cumberland Mountains sub-ecoregion and, except for a very small portion, it lies within the primary MTM region (Woods et al. 1999). The coal mining industry has been active in this watershed for many years. Both surface and underground mining have occurred in the past and presently continue to be mined. There were no unmined sites sampled from this watershed (Green et al. 2000 Draft).

The U.S. EPA Region 3 sampled eight sites in the Clear Fork Watershed (Figure 2-4, Table 2-3). Brief descriptions of these sites are given below and more complete descriptions are given in Green et al. (2000 Draft). The U.S. EPA Region 3 Site MT79 was established on Davis Fork. It was located downstream of mining activities. Site MT78 was established on Raines Fork. It was located downstream of historical contour and underground mining. Site MT81 was

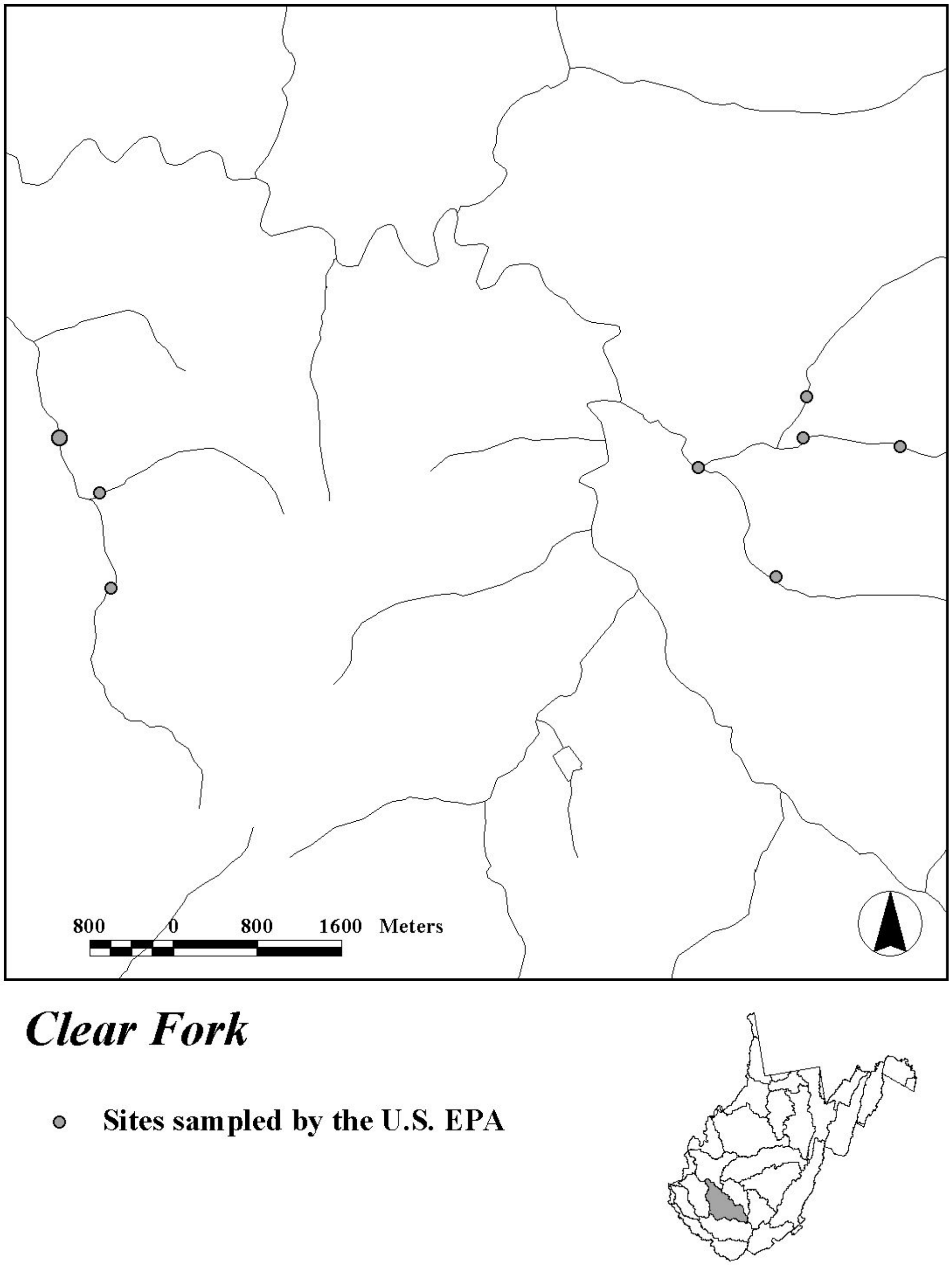


Figure 2-4. Sites sampled in the Clear Fork Watershed.

Table 2-3. Sites sampled in the Clear Fork Watershed.

Site ID/Organization	Stream Name	EIS Class
U.S. EPA Region 3		
MT79	Davis Fork	Mined
MT78	Raines Fork	Mined
MT81	Sycamore Creek	Mined
MT75	Toney Fork	Filled/Residential
MT70	Toney Fork	Filled/Residential
MT69	Ewing Fork	Mined/Residential
MT64	Buffalo Fork	Filled
MT62	Toney Fork	Filled/Residential

established on Sycamore Creek. It was located downstream of historical contour and underground mining and it is downstream of a plant that treats mine effluent. Site MT75 was established on Toney Fork. It was located downstream of five VFs, MTM activities and numerous residences. Site MT70 was established approximately 1 km (0.6 mi) downstream of Site MT75. It was located downstream of six VFs, MTM activities and numerous residences. This site was only sampled during autumn 1999 and winter and spring 2000. Site MT69 was established on Ewing Fork. It was located downstream of some historical contour and underground mining activities and a residence. Site MT64 was established on Buffalo Fork. It was located downstream of historical contour mining, current MTM activities, five VFs and a small amount of pasture. Site MT62 was established on Toney Fork. It was located downstream of 11 VFs, numerous residences and a small amount of pasture (Green et al. 2000 Draft).

2.3.4. Twentymile Creek Watershed

Twentymile Creek drains portions of Clay, Fayette, Kanawha, and Nicholas Counties, West Virginia. It generally flows to the southwest where it joins the Gauley River at Belva, West Virginia. Except for a small area on the western edge of the watershed, it is within the primary MTM region and the entire watershed lies within the Cumberland Mountains sub-ecoregion (Woods et al. 1999). Upstream of Vaughn, West Virginia, the watershed is uninhabited and logging, mining, and natural gas extracting are the primary activities. The majority of the mining activity has been conducted recently. Downstream of Vaughn, there are numerous residences and a few small communities (Green et al. 2000 Draft).

The U.S. EPA Region 3 sampled seven sites in the Twentymile Creek Watershed (Figure 2-5, Table 2-4). Brief descriptions of these sites are given below and more complete description

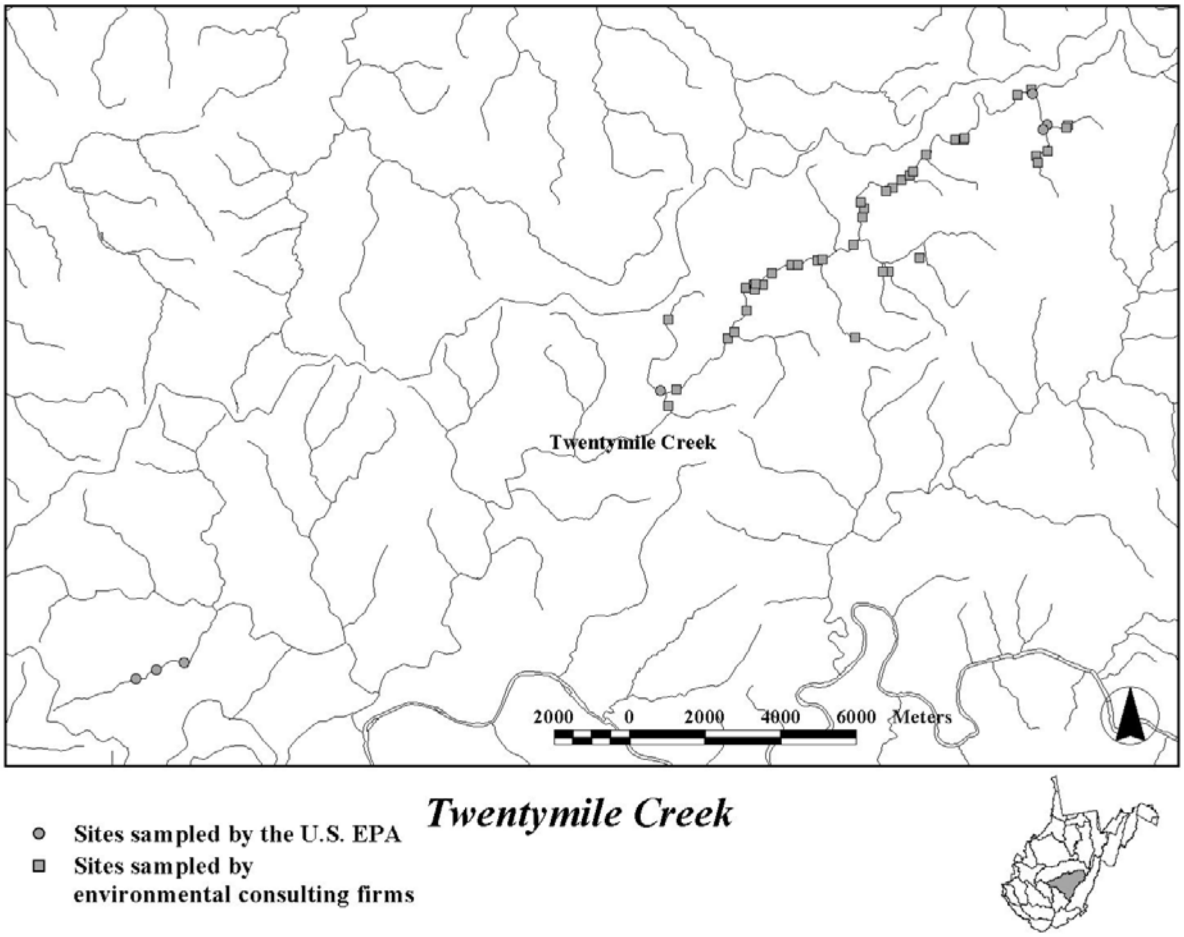


Figure 2-5. Sites sampled in the Twentymile Creek Watershed.

are given in Green et al. (2000 Draft). The U.S. EPA Region 3 Site MT95 was established on Neil Branch. There were no known disturbances upstream of this site. Site MT91 was established on Rader Fork. The only known disturbance to this site was a road with considerable coal truck traffic. Site MT87 was established on Neff Fork downstream of three VFs and a mine drainage treatment plant. Site MT86 was located on Rader Fork downstream of Site MT91 and Neff Fork and it was, therefore, downstream of three VFs and a mine drainage treatment plant. Site MT103 was established on Hughes Fork. It was downstream of six VFs. Site MT98 was established on Hughes Fork. It was downstream of Site MT103 and eight VFs. Site MT104 was established on Hughes Fork. It was downstream of Site MT103, Site MT98, eight VFs and a sediment pond (Green et al. 2000 Draft).

Table 2-4. Sites sampled in the Twentymile Creek Watershed. Equivalent sites are noted parenthetically.

Site ID/Organization	Stream Name	EIS Class
U.S. EPA Region 3		
MT95 (=Neil-5)	Neil Branch	Unmined
MT91	Rader Fork	Unmined
MT87 (=Rader-4)	Neff Fork	Filled
MT86 (=Rader-7)	Rader Fork	Filled
MT103	Hughes Fork	Filled
MT98	Hughes Fork	Filled
MT104	Hughes Fork	Filled
BMI		
Rader 8	Twentymile Creek	Additive
Rader 9	Twentymile Creek	Additive
PMC-TMC-36	Twentymile Creek	Additive
PMC-TMC-35	Twentymile Creek	Additive
PMC-TMC-34	Twentymile Creek	Additive
PMC-TMC-33	Twentymile Creek	Additive
PMC-TMC-31	Twentymile Creek	Additive
PMC-TMC-30	Twentymile Creek	Additive
PMC-TMC-29	Twentymile Creek	Additive
PMC-TMC-28	Twentymile Creek	Additive
PMC-TMC-27	Twentymile Creek	Additive
PMC-TMC-26	Twentymile Creek	Additive
PMC-7	Twentymile Creek	Additive
PMC-6	Twentymile Creek	Additive
PMC-5	Twentymile Creek	Additive
PMC-TMC-4	Twentymile Creek	Additive
PMC-TMC-5	Twentymile Creek	Additive
PMC-TMC-314	Twentymile Creek	Additive
PMC-TMC-2	Twentymile Creek	Additive
PMC-TMC-1	Twentymile Creek	Additive

Continued

Table 2-4. Continued.

Site ID/Organization	Stream Name	EIS Class
BMI (Continued)		
PMC-HWB-1	Twentymile Creek	Additive
PMC-HWB-2	Twentymile Creek	Additive
Neil-6 (=Fola 48)	Twentymile Creek	Additive
Neil-7 (=Fola 49)	Twentymile Creek	Additive
Neil-2 (=Fola 53)	Neil Branch	Unmined
Neil-5 (=MT95)	Neil Branch	Unmined
Rader-1	Laurel Run	Unmined
Rader-2	Rader Fork	Unmined
Rader-3	Trib. to Rader	Unmined
Rader-4 (=MT87)	Neff Fork	Filled (2)
Rader-5	Neff Fork	Filled (2)
Rader-6	Trib. to Neff	Filled (1)
Rader-7 (=MT86)	Rader Fork	Filled (2)
PMC-1	Sugarcamp Branch	Filled (1)
PMC-11	Right Fork	Filled (1)
PMC-12	Road Fork	Filled (1)
PMC-15	Tributary to Robinson Fork.	Filled (1)
POTESTA		
Fola 33	Twentymile Creek	Additive
Fola 36	Twentymile Creek	Additive
Fola 37	Twentymile Creek	Additive
Fola 38	Twentymile Creek	Additive
Fola 48 (=Neil-6)	Twentymile Creek	Additive
Fola 49 (=Neil-7)	Twentymile Creek	Additive
Fola 39	Peachorchard Branch	Filled (2 small)
Fola 40	Peachorchard Branch	Filled (1 small)
Fola 45	Peachorchard Branch	Unmined
Fola 53 (=Neil-2)	Neil Branch	Unmined

2.3.5. Island Creek Watershed

Island Creek generally flows north toward Logan, West Virginia where it enters the Guyandotte River. The entire watershed is confined to Logan County. With the exception of the northern portion, the watershed lies within the primary MTM region and the entire watershed lies within the Cumberland Mountains sub-ecoregion (Woods et al. 1999). Extensive underground mining has occurred in the watershed for many years. As the underground reserves have been depleted and the economics of the area have changed, surface mining has played a larger role in the watershed (Green et al. 2000 Draft).

The U.S. EPA Region 3 sampled eight sites in the Island Creek Watershed (Figure 2-6, Table 2-5). Brief descriptions of these sites are given below and more complete descriptions are given in Green et al. (2000 Draft). The U.S. EPA Region 3 Site MT50 was located on Cabin Branch in the headwaters of the sub-watershed and upstream of any disturbances. Site MT51 was also established on Cabin Branch located downstream of Site MT50 and a gas well. Site MT107 was established on Left Fork in the spring of 2000, located upstream of the influence of VFs. Site MT52 was established near the headwaters of Cow Creek. It was located upstream of VFs, but downstream of an underground mine entrance, a small VF and a sediment pond. Site MT57B was established on Hall Fork for sampling in the spring and summer 1999. It was located downstream of a sediment pond and a VF. In the autumn 1999, Site MT57 was established near the mouth of Hall fork. It was farther downstream than Site MT57B and was downstream of a sediment pond and a VF. Site MT60 was established on Left Fork, downstream of Site MT107. It was located downstream of two existing VFs and three proposed VFs. Site MT55 was established on Cow Creek, downstream of Site MT52. It was located downstream of four VFs associated with MTM, one VF associated with underground mining, residences, a log mill, orchards, vineyards, cattle, and a municipal sewage sludge disposal site (Green et al. 2000 Draft).

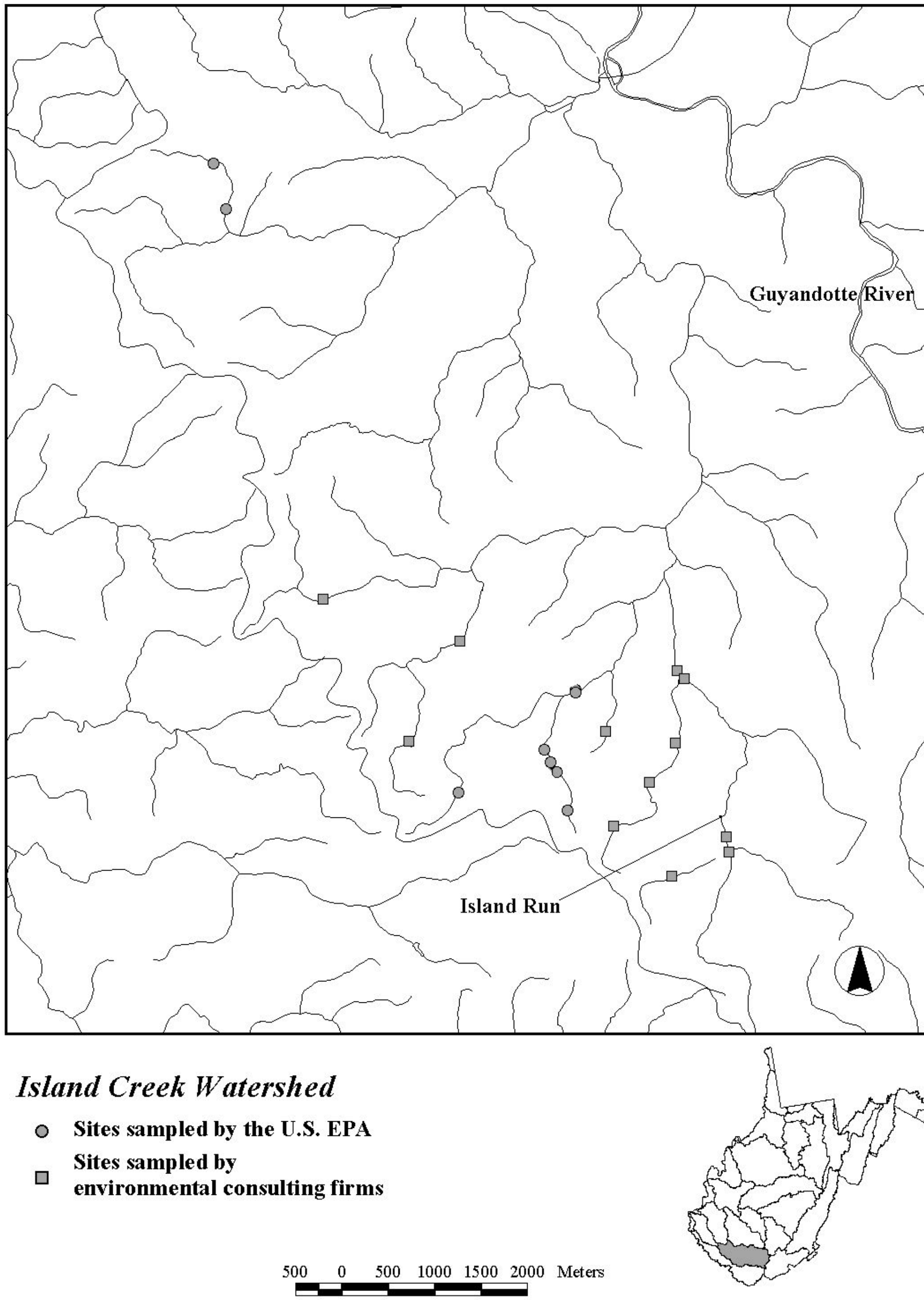


Figure 2-6. Sites sampled in the Island Creek Watershed.

Table 2-5. Sites sampled in the Island Creek Watershed.

Site	Stream Name	EIS Class
U.S. EPA Region 3		
MT50	Cabin Branch	Unmined
MT51	Cabin Branch	Unmined
MT107	Left Fork	Unmined
MT52	Cow Creek	Filled
MT57B	Hall Fork	Filled
MT57	Hall Fork	Filled
MT60	Left Fork	Filled
MT55	Cow Creek	Filled/Residential
BMI		
Mingo 34		Filled (1)
Mingo 41		Filled (2)
Mingo 39		Filled (1) + old mining
Mingo 16		Unmined
Mingo 11		Unmined
Mingo 2		Unmined
Mingo 86		Unmined
Mingo 62		Unmined
Mingo 38	Island Creek	Additive
Mingo 24	Island Creek	Additive
Mingo 23	Island Creek	Additive

2.3.6. Twelvepole Creek Watershed

The East Fork of the Twelvepole Creek Watershed drains portions of Mingo, Lincoln, and Wayne Counties, West Virginia. The stream flows northwest to the town of Wayne, West Virginia where it joins the West Fork of Twelvepole Creek then continues to flow on into the Ohio River at Huntington, West Virginia. The East Fork of Twelvepole Creek is impounded by East Lynn Lake near Kiahsville, West Virginia in Wayne County (West Virginia DEP, Personal Communication).

The East Fork of the Twelvepole Creek Watershed encompasses approximately 445 km^2 (172 mi^2) of drainage area and is 93.3% forested. Prior to 1977, very little mining had occurred in the watershed south of East Lynn Lake. Since 1987, several surface mining operations have been employed in the Kiah Creek and the East Fork of Twelvepole Creek watersheds (Critchley 2001). Currently, there are 23 underground mining, haul road and refuse site permits, and 21 surface mining permits in the watershed (West Virginia DEP, Personal Communication).

REIC has conducted biological evaluations in the East Fork of the Twelvepole Creek Watershed since 1995. Five stations have been sampled on Kiah Creek (Figure 2-7, Table 2-6). Station BM-003A was located in the headwaters of Kiah Creek, upstream from surface mining and residential disturbances. Station BM-003 was located near the border of Lincoln and Wayne Counties and it was downstream from several surface mining operations and several residential disturbances. Station BM-004 was located on Kiah Creek downstream from the surface mining operations on Queens Fork and Vance Branch, near the confluence of Jones Branch, downstream from Trough Fork, and downstream of residential disturbances. Station BM-004A was located downstream from the confluence of Big Laurel Creek, surface mining operations and residential disturbances.

Two stations were sampled in Big Laurel Creek (Figure 2-7, Table 2-6). This tributary has only residential disturbances in its watershed. Station BM-UBLC was located near the headwaters of Big Laurel Creek. Station BM-DBLC was located near the confluence of Big Laurel Creek with Kiah Creek.

Eight stations were sampled on the East Fork of Twelvepole Creek (Figure 2-7, Table 2-6). Station BM-001A was located just downstream from confluence of McCloud Branch and was downstream of a residential disturbance. Station BM-001C was located downstream of the confluence of Laurel Branch which currently has a VF, additional proposed VFs, and residences. Station BM-001B was located downstream of the confluence of Wiley Branch which has residences, numerous current VFs and additional VFs under construction or being proposed. Station BM-001 was located upstream from the confluence of Bluewater Branch but downstream from the Wiley Branch and Laurel Branch surface mining operations and residences. Station BM-010 was downstream from the Franks Branch mining operation and residences. Station BM-011 was located downstream from the Maynard Branch operations and residences. Station BM-002 was located downstream from the Devil Trace surface mining operation and residences. Station BM-002A was located downstream of Milam Creek and all mining operations and residences in this sub-watershed.

Two stations were located in Milam Creek, a tributary of the East Fork of Twelvepole Creek (Figure 2-7, Table 2-6). Milam Creek has no mining operations or residential disturbances in its watershed. Station BM-UMC was located near the headwaters of Milam Creek and station BM-DMC was located near the confluence of Milam Creek with the East Fork of Twelvepole Creek.

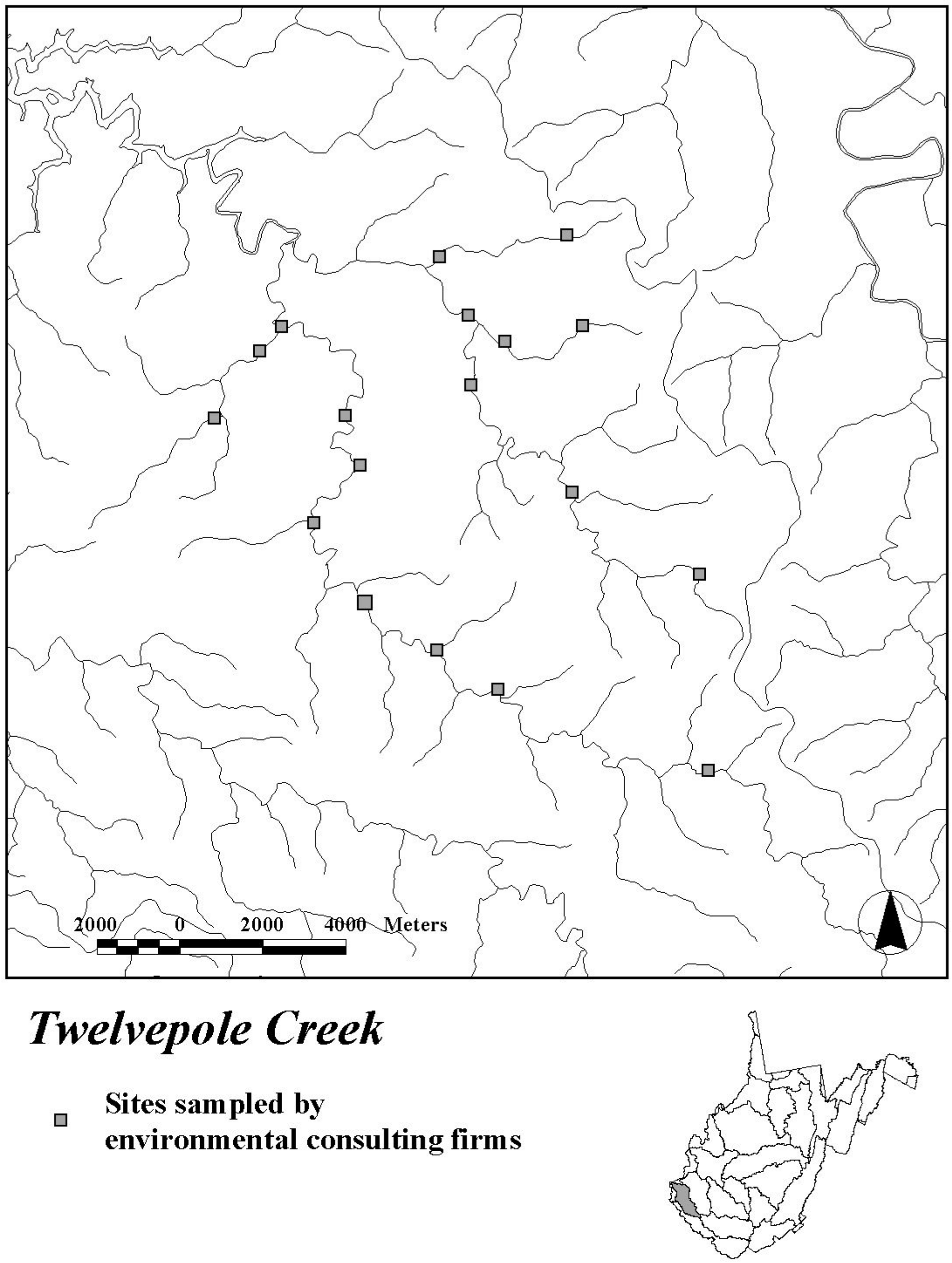


Figure 2-7. Sites sampled in the Twelvepole Creek Watershed.

Table 2-6. Sites sampled in the Twelvepole Creek Watershed. Equivalent sites are noted parenthetically.

Site ID/Organization	Stream Name	EIS Class
REIC		
BM-003A	Kiah Creek	Additive
BM-003	Kiah Creek	Additive
BM-004	Kiah Creek	Additive
BM-004A	Kiah Creek	Additive
BM-DBLC	Big Laurel Creek	Unmined
BM-UBLC	Big Laurel Creek	Unmined
BM-001A	Twelvepole Creek	Additive
BM-001C	Twelvepole Creek	Additive
BM-001B	Twelvepole Creek	Additive
BM-001	Twelvepole Creek	Additive
BM-010	Twelvepole Creek	Additive
BM-011	Twelvepole Creek	Additive
BM-002	Twelvepole Creek	Additive
BM-002A	Twelvepole Creek	Additive
BM-UMC	Milam Creek	Unmined
BM-DMC	Milam Creek	Unmined
BM-005	Trough Fork	Additive
BM-006	Trough Fork	Additive

2.4. Data Collection Methods

The data for this study were generated by five different organizations (i.e., U.S. EPA Region 3, PSU, BMI, POTESTA and REIC). The methods used to collect each of the four different types of data (i.e., habitat, water quality, fish assemblage and macroinvertebrate assemblage) are described below. This information is summarized in tabular form in Appendix A.

2.4.1. Habitat Assessment Methods

2.4.1.1. U.S. EPA Region 3 Habitat Assessment

The U.S. EPA Region 3 used the RBP (Barbour et al. 1999) to collect habitat data at each site. Although some parameters require observations of a broader section of the catchment area, the habitat data were primarily collected in a 100-m reach that includes the portion of the stream where biological data (i.e., fish and macroinvertebrate samples) were collected. The RBP habitat assessment evaluates ten parameters (Appendix A).

The U.S. EPA Region 3 measured substrate size and composition in order to help determine if excessive sediment was causing any biological impairments (Kaufmann and Robison 1998). Numeric scores were assigned to the substrate classes that are proportional to the logarithm of the midpoint diameter of each size class (Appendix A).

2.4.1.2. BMI Habitat Assessment

The Standard Operating Procedures (SOPs) submitted by BMI make no mention of habitat assessment methods.

2.4.1.3. POTESTA Habitat Assessment

POTESTA collected physical habitat data using methods outlined in Kaufmann et al. (1999) or in Barbour et al. (1999, Appendix A). The habitat assessments were performed on the same reaches from which biological sampling was conducted. A single habitat assessment form was completed for each sampling site. This assessment form incorporated features of the selected sampling reach as well as selected features outside the reach but within the catchment area. Habitat evaluations were first made on in-stream habitat, followed by channel morphology, bank structural features, and riparian vegetation.

2.4.1.4. REIC Habitat Assessment

The SOPs submitted by REIC make no mention of habitat assessment methods.

2.4.2. Water Quality Assessment Methods

2.4.2.1. U.S. EPA Water Quality Assessment

The U.S. EPA Region 3 measured conductivity, pH, temperature and dissolved oxygen (DO) *in situ* and the flow rate of the stream at the time of sampling. Each of these measurements was made once at each site during each field visit. The U.S. EPA Region 3 also collected water samples for laboratory analyses. These samples were analyzed for the parameters given in Table 2-7.

2.4.2.2. BMI Water Quality Assessment

The SOPs submitted by BMI make no mention of water quality assessment methods.

2.4.2.3. POTESTA Water Quality Assessment

POTESTA measured conductivity, pH, temperature and DO *in situ.* These measurements were taken once upstream from each biological sampling site, and were made following the protocols outlined in U.S. EPA (1979). The stream flow rate was also measured at or near each sampling point. One of the three procedures (i.e., velocity-area, time filling, or neutrally buoyant object) outlined in Kaufmann (1998) was used at each site. POTESTA also collected water samples at each site directly upstream of the location of the biological sampling. These samples were analyzed in the laboratory for the suite of analytes listed in Table 2-7.

2.4.2.4. REIC Water Quality Assessment

REIC recorded water body characteristics (i.e., size, depth and flow) and site location at each site. Grab samples were collected and delivered to the laboratory for analysis. The SOPs submitted by REIC make no mention of which analytes were measured in the laboratory.

2.4.3. Fish Assemblage Methods

2.4.3.1. PSU Fish Assemblage Assessment

The PSU, in consultation with personnel from U.S. EPA Region 3, sampled fish assemblages at 58 sites in West Virginia. The fish sampling procedures generally followed those in McCormick and Hughes (1998). Fish were collected by making three passes using a backpack electrofishing unit. Each pass proceeded from the downstream end of the reach to the upstream

Table 2-7. Parameters used by each organization for lab analyzed water samples.

Parameter	Organizations			
	U.S. EPA	BMI	POTESTA	REIC
Acidity	Yes	Unknown	Yes	Unknown
Alkalinity	Yes	Unknown	Yes	Unknown
Chloride	Yes	Unknown	Yes	Unknown
Hardness	Yes	Unknown	Yes	Unknown
Nitrate(NO_3) + Nitrite (NO_2)	Yes	Unknown	Yes	Unknown
Sulfate	Yes	Unknown	Yes	Unknown
Total Suspended Solids (TSS)	Yes	Unknown	Yes	Unknown
Total Dissolved Solids (TDS)	Yes	Unknown	Yes	Unknown
Total Organic Carbon (TOC)	Yes	Unknown	Yes	Unknown
Coarse Particulate Organic Matter (CPOM)	No	Unknown	Yes	Unknown
Fine Particulate Organic Matter (FPOM)	No	Unknown	Yes	Unknown
Total Dissolved Organic Carbon (TDOC)	Yes	Unknown	No	Unknown
Total Aluminum	Yes	Unknown	Yes	Unknown
Dissolved Aluminum	Yes	Unknown	Yes	Unknown
Total Antimony	Yes	Unknown	Yes	Unknown
Total Arsenic	Yes	Unknown	Yes	Unknown
Total Barium	Yes	Unknown	No	Unknown
Total Beryllium	Yes	Unknown	Yes	Unknown
Total Cadmium	Yes	Unknown	Yes	Unknown
Total Calcium	Yes	Unknown	Yes	Unknown
Total Chromium	Yes	Unknown	Yes	Unknown
Total Cobalt	Yes	Unknown	No	Unknown
Total Copper	Yes	Unknown	Yes	Unknown
Total Iron	Yes	Unknown	Yes	Unknown

(Continued)

Table 2-7. Continued.

Parameter	Organizations			
	U.S. EPA	BMI	POTESTA	REIC
Dissolved Iron	Yes	Unknown	Yes	Unknown
Total Lead	Yes	Unknown	Yes	Unknown
Total Magnesium	Yes	Unknown	Yes	Unknown
Total Manganese	Yes	Unknown	Yes	Unknown
Dissolved Manganese	Yes	Unknown	Yes	Unknown
Total Mercury	Yes	Unknown	Yes	Unknown
Total Nickel	Yes	Unknown	Yes	Unknown
Total Potassium	Yes	Unknown	Yes	Unknown
Total Phosphorous	Yes	Unknown	Yes	Unknown
Total Selenium	Yes	Unknown	Yes	Unknown
Total Silver	Yes	Unknown	Yes	Unknown
Total Sodium	Yes	Unknown	Yes	Unknown
Total Thallium	Yes	Unknown	Yes	Unknown
Total Vanadium	Yes	Unknown	No	Unknown
Total Zinc	Yes	Unknown	Yes	Unknown

end of the reach. Block nets were used only when natural barriers (i.e., shallow riffles) were not present. The fish collected from each pass were kept separate. Fish were identified to the species level and enumerated. The standard length of each fish was measured to the nearest mm and each fish was weighed to the nearest 0.01 g.

2.4.3.2. BMI Fish Assemblage Assessment

The SOPs submitted by BMI make no mention of fish assemblage assessment methods.

2.4.3.3. POTESTA Fish Assemblage Assessment

POTESTA collected fish by using the three-pass depletion method of Van Deventer and Platts (1983) with a backpack electrofishing unit. Each of the three passes proceeded from the downstream end of the reach to the upstream end of the reach. The fish collected from each pass were kept separate. Additional passes were made if the numbers of fish did not decline during the two subsequent passes. Game fish and rare, threatened or candidate (RTC) fish species were identified, their total lengths were recorded to the nearest mm, and their weights were recorded to the nearest g. With the exception of small game and non-RTC fish, the captured fish were released. Small game fish and non-RTC fish that were collected during each pass were preserved separately and transported to the laboratory for analysis. Preserved fish were identified and weighed to the nearest g.

2.4.3.4. REIC Fish Assemblage Assessment Methods

REIC collected fish by setting block nets across the stream and perpendicular to the stream banks, then progressing upstream with a backpack electrofishing unit. The entire reach was surveyed three times. After each survey, all large fish were identified using guidelines given by Trautman (1981) and Stauffer et al. (1995). The total lengths of the fish were measured to the nearest mm and they were weighed to the nearest g. After all three passes were completed, the large fish were returned to the stream. Small fish which required microscopic verification of their identification were preserved and transported to the laboratory. Once in the laboratory, small fish were identified using guidelines given by Trautman (1981) and Stauffer et al. (1995). After identification, the total lengths of the fish were measured to the nearest mm, they were weighed to the nearest 0.1 g and their identifications were reconfirmed.

2.4.4. Macroinvertebrate Assemblage Methods

2.4.4.1. U.S. EPA Region 3 Macroinvertebrate Assemblage Assessment

The U.S. EPA's Region 3 used RBPs to assess benthic macroinvertebrate assemblages (Barbour et al. 1999). Samples were collected from riffles only. A 0.5 m wide rectangular dip net with 595-µm mesh was used to collect organisms in a 0.25 m^2 area upstream of the net. At each site, four samples were taken, and composited into a single sample, representing a total area sampled of approximately 1.0 m^2. The RBPs recommend the total area sampled to be 2.0 m^2 but that was reduced to 1.0 m^2 for this study due to the small size of the streams. Benthic macroinvertebrate samples were collected in each season except when there was not enough flow for sampling. Approximately 25% of the sites were sampled in replicate to provide information on within-season and within-site variability. These replicate samples were collected at the same time, usually from adjacent locations in the same riffle.

The samples collected by the U.S. EPA Region 3 were sub-sampled in the laboratory so that ⅛ of the composite samples were picked. All organisms in the sub-sample were identified to the family level, except for oligochetes and leeches, which were identified to the class level. Organisms were identified using published taxonomic references (i.e., Pennak 1989, Pecharsky et al. 1990, Stewart and Stark 1993, Merritt and Cummins 1996, Westfall and May 1996, Wiggins 1998).

2.4.4.2. BMI Macroinvertebrate Assemblage Methods

BMI collected samples using a kick net with a 0.5 m width and a 600 µm mesh size. The net was held downstream of the 0.25 m^2 area that was to be sampled. All rocks and debris that were in the 0.25 m^2 area were scrubbed and rinsed into the net and removed from the sampling area. Then, the substrate in the 0.25 m^2 area was vigorously disturbed for 20 seconds. This process was repeated four times at each sampling site and the four samples were composited into a single sample.

BMI also collected samples using a 0.09 m^2 (1.0 ft^2) Surber sampler with a 600 µm mesh size. The frame of the sampler was placed on the stream bottom in the area that was to be sampled. All large rocks and debris that were in the 1.0-ft^2 frame were scrubbed and rinsed into the net and removed from the sampling area. Then, the substrate in the 1.0 ft^2 frame was vigorously disturbed for 20 seconds. In autumn 1999 and spring 2000, no samples were collected with Surber samplers. In autumn 2000, six Surber samples were collected at each site, and in spring 2001, four Surber samples were collected. All Surber samples were kept separate.

In the laboratory, the samples were rinsed using a sieve with 700 µm mesh. All macroinvertebrates in the samples were picked from the debris. Each organism was identified to the taxa level specified in the project study plan.

2.4.4.3. POTESTA Macroinvertebrate Assemblage Assessment

POTESTA collected samples of macroinvertebrates using a composite of four 600 µm mesh kick net samples and following the U.S. EPA's RBPs (Barbour et al. 1999). For each of the four kick net samples, all large debris within a 0.25 m^2 area upstream of the kick net were brushed into the net. Then, the substrate in the 0.25 m^2 area was disturbed for 20 seconds. Once all four kick net samples were collected, they were composited into a single labeled jar.

POTESTA used Surber samplers to collect macroinvertebrate samples at selected sites. Surber samples were always collected in conjunction with kick net samples. At sites selected for quantitative sampling, a Surber sampler was placed on the stream bottom in a manner so that all sides were flat against the stream bed. Large cobble and gravel within the frame were thoroughly brushed and the substrate within the frame was disturbed for a depth of up to 7.6 cm

(3.0 in) with the handle of the brush. The sample was then placed in a labeled jar. The SOPs submitted by POTESTA make no mention of the area sampled or the number of samples collected with the Surber samplers.

In the laboratory, all organisms in the samples were identified by qualified freshwater macroinvertebrate taxonomists to the lowest practical taxonomic levels using Wiggins (1977), Stewart and Stark (1988), Pennak (1989) and Merritt and Cummins (1996). To ensure the quality of the identifications, 10% of all samples were re-picked and random identifications were reviewed.

2.4.4.4. REIC Macroinvertebrate Assemblage Assessment

REIC collected macroinvertebrate samples using a 600 μm mesh D-frame kick net. The kick net was positioned in the stream with the net outstretched with the cod end on the downstream side. The person using the net then used a brush to scrub any rocks within a 0.25 m^2 area in front of the net, sweeping dislodged material into the net. The person then either kicked up the substrate in the 0.25 m^2 area in front of the net or knelt and scrubbed the substrate in that area with one hand. The substrate was scrubbed or kicked for up to three minutes, with the discharged material being swept into the net. This procedure was repeated four times so that the total area sampled was approximately 1.0 m^2. Once collected, the four samples were composited into a single sample.

REIC also collected macroinvertebrate samples using Surber samplers with sampling areas of 0.09 m^2 (1 ft^2). These samplers were only used in areas where the water depth was less than 0.03 m (1 ft). The SOPs submitted by REIC make no mention of the mesh size used in the Surber samplers. The Surber sampler was placed in the stream, with the cod end of the net facing downstream. The substrate within the 1 ft^2 area was scrubbed for a period of up to three minutes and to a depth of approximately 7.62 cm (3 in). While being scrubbed, the dislodged material was swept into the net. After scrubbing was complete, rocks in the sampling area were checked for clinging macroinvertebrates. Once they had been removed, the material in the net was rinsed and the sample was deposited into a labeled sampling jar. Three Surber samples were collected at each site where they were used. These samples were not composited.

In the laboratory, REIC processed all samples individually. Samples were poured through a 250 μm sieve and rinsed with tap water. The sample was then split into quarters by placing it on a sub-sampling tray fitted with a 500 μm screen and spread evenly over the tray. The sample in the first quarter of the tray was removed, placed into petri dishes, and placed under a microscope so that all macroinvertebrates could be separated from the detritus. If too few organisms (this number is not specified in the SOPs submitted by REIC) were in the first quarter, then additional quarters were picked until enough organisms had been retrieved from the sample.

REIC used three experienced aquatic taxonomists to identify macroinvertebrates. They identified the organisms under microscopes to their lowest practical taxonomic level, usually Genus. Chironomids were often identified to the Family level and annelids were identified to the Class level. As taxonomic guides, REIC used Pennak (1989), Stewart and Stark (1993), Wiggins (1995), Merritt and Cummins (1996) and Westfall and May (1996).

3. DATA ANALYSES

3.1. Database Organization

3.1.1. Data Standardization

All of the methods used to collect and process fish samples were compatible, thus it was not necessary to standardize the fish data prior to analysis. However, there were differences among the methods used to collect and process the benthic macroinvertebrate data which made it necessary to standardize the macroinvertebrate data to eliminate potential biases before data analysis.

The benthic macroinvertebrate database was organized by sampling device (i.e., D-frame kick net or Surber sampler). Since not all organizations used Surber samplers and not all organizations that used Surber samplers employed the same methods (Section 2.4.4), Surber data were not used for the analyses in this report. All of the sampling organizations did use D-frame kick nets with comparable field methods to collect macroinvertebrate samples. Use of the data collected by D-frame kick net provides unbiased data with respect to the types, densities and relative abundances of organisms collected. However, while identifying organisms in the laboratory, the U.S. EPA sub-sampled 1/8 of the total material (with some exceptions noted in the data), REIC sub-sampled 1/4 of the total material (with some exceptions), and BMI and POTESTA counted the entire sample. To eliminate bias of the reported taxa richness data introduced by different sizes of sub-samples, all organism counts were standardized to a 1/8 sub-sample of the total original material. (Appendices A and E)

3.1.2. Database Description

3.1.2.1. Description of Fish Database

The fish database included 126 sampling events where the collection of a fish sample had been attempted and the location and watershed area were known. Of these, five were regional reference samples from Big Ugly Creek, outside of the study watersheds. Catchments with areas of less than 2.0 km^2 and samples with fewer than ten fish were excluded from the analysis (section 4.1.1). A summary of the remaining 99 samples is shown in Table 3-1.

The Mined/Residential EIS Class consisted of only two samples. Due to insufficient sample size for adequate statistical analysis, this class was eliminated.

Table 3-1. Number of fish sites and samples in the study area, by EIS class and watershed. The first numbers in the cells represent the number of sites and the numbers in parentheses represent the numbers of samples.

Watershed	Unmined	Filled	Mined	Filled/Res	Additive	Total
Mud River	3, (4)	4, (8)		1, (3)	1, (2)	9, (17)
Island Creek	1, (1)	2, (3)		2, (2)	2, (2)	7, (8)
Spruce Fork	1, (1)	3, (3)	1, (1)	3, (3)	1, (1)	9, (9)
Clear Fork		1, (1)	3, (3)	3, (3)		7, (7)
Twenty Mile Creek	5, (5)	7, (7)			7, (16)	19, (28)
Twelvepole Creek[1]	4, (6)				12, (24)	16, (30)
Total	14, (17)	17, (22)	4, (4)	9, (11)	23, (45)	67, (99)

[1]All sites in Twelvepole Creek were sampled by REIC; and were Additive and Unmined only.

3.1.2.2. Description of Macroinvertebrate Database

A total of 282 macroinvertebrate samples were collected from 66 sites in six watersheds (Table 3-2). The samples from sites in the Mined/Residential EIS class were removed from the analysis because there were too few sites (i.e., $n < 3$) to conduct statistical comparisons.

The U.S. EPA Region 3 collected a duplicate sample from the same site, on the same day, 42 different times, in five of the six sampled watersheds (i.e., no duplicate samples were taken from the Twelvepole Creek Watershed). The WVSCI, the total # of families, and the total number of EPT were highly correlated for duplicate samples (Table 3-3). Green et al. (2000) found similar results with raw metric scores. Because of these correlations and in order to avoid inflating the sample size, the only U.S. EPA Region 3 duplicate samples used for analyses were those that were labeled Replicate Number 1.

One site in Twentymile Creek was sampled by more than one organization the same season (i.e., autumn 2000 and winter 2001). To avoid sample size inflation, the means of the sample values were used for each season, thereby reducing the total number of samples. The means were used instead of the values from one of the samples because the samples were collected between three and five weeks apart. The U.S. EPA and two other organizations sampled the same site in the autumn 1999 and the winter 2000. In this case, the U.S. EPA data were used because these data did not require making a correction for sub-sampling.

Table 3-2. Number of sites and D-frame kick net samples available in each watershed and

in each EIS class.

Watershed	Unmined		Filled		Filled/ Residential		Mined		Mined/ Residential[1]		Total	
	Site	Samp	Site	Samp	Site	Samp	Site	Samp	Site	Samp	Site	Samp
Mud River	3	11	3	19	1	6	1	1	1	5	9	42
Island Creek	7	13	6	21	1	6	1	1	0	0	15	41
Spruce Fork	2	8	3	18	2	14	1	5	0	0	8	45
Clear Fork	0	0	1	8	3	12	3	12	1	7	8	39
Twentymile Creek	7	32	15	71	0	0	0	0	0	0	22	103
Twelvepole Creek	4	12	0	0	0	0	0	0	0	0	4	12
Total	23	76	28	137	7	38	6	19	2	12	66	282

(EIS Class spans Unmined through Mined/Residential.)

[1]Because there were only two Mined/Residential sites, this EIS class was not used in any of the analyses for this report.

The samples taken from the Twelvepole Creek Watershed (four Unmined EIS class sites) were made up of a mix of D-frame kick net and Surber sampler data that were inseparable by sampler type. Therefore, these data could not be standardized and were removed from the EIS analysis for the D-frame kick net data set.

These data reduction procedures lowered the total number of D-frame kick net samples for EIS analysis from 282 (Table 3-2) to 215 (Table 3-4). The U.S. EPA Region 3 collected 150 (69.8%) of these samples and the other organizations collected 65 (30.2%) of these samples. Hence, these other organizations provided 43% more samples for analysis than the U.S. EPA Region 3 had collected. These samples also provided information from 23 additional sites in the Unmined, Filled, Filled/Residential, and Mined EIS classes. However, these additional samples were not distributed evenly across watersheds and EIS classes. Only the U.S. EPA Region 3 collected data from the Mud River, Spruce Fork, and Clear Fork Watersheds and the majority (85%) of the samples collected by the private organizations were collected from the Twentymile Creek Watershed. As a result, the additional data provided by the private organizations were skewed to conditions in the Twentymile Creek Watershed, especially for sites in the Filled EIS class. Furthermore, 100% of the data collected by the private organizations during autumn 2000 and winter 2001 were collected from the Twentymile Creek Watershed. Therefore, comparisons made using data that were collected during these two seasons do not represent conditions across the entire study area, and have less than half the number of samples that were collected during the other seasons.

Table 3-3. Correlation and significance values for the duplicate samples collected by the

U.S. EPA Region 3 with the WVSCI and standardized WVSCI metrics.

Metric	R	p-value
Total Number of Families Rarefied to 100 individuals	0.863	<0.001
Total Number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) Families Rarefied to 100 individuals	0.897	<0.001
WVSCI Rarefied to 100 individuals	0.945	<0.001

Table 3-4. Number of sites and D-frame kick net samples used for comparing EIS classes after the data set had been reduced.

Watershed		EIS Class								Total	
		Unmined		Filled		Filled/ Residential		Mined			
		Site	Samp	Site	Samp	Site	Samp	Site	Samp	Site	Samp
Mud River	U.S. EPA	3	9	3	15	1	5	1	1	8	30
	Private	0	0	0	0	0	0	0	0	0	0
Island Creek	U.S. EPA	3	7	4	15	1	5	0	0	8	27
	Private	4	6	2	3	0	0	1	1	7	10
Spruce Fork	U.S. EPA	2	7	3	13	2	10	1	5	8	35
	Private	0	0	0	0	0	0	0	0	0	0
Clear Fork	U.S. EPA	0	0	1	5	3	10	3	9	7	24
	Private	0	0	0	0	0	0	0	0	0	0
Twenty-mile Creek	U.S. EPA	2	9	5	25	0	0	0	0	7	34
	Private	6	18	10	37	0	0	0	0	16	55
Total	U.S. EPA	10	32	16	73	7	30	6	15	38	150
	Private	10	24	12	40	0	0	1	1	23	65

3.2. Data Quality Assurance/Quality Control

The biological, water chemistry, and habitat data were received in a variety of formats. Data were exported from their original formats into the Ecological Data Application System (EDAS), a customized relational database application (Tetra Tech, Inc., 1999). The EDAS allows data to be aggregated and analyzed by customizing the pre-designed queries to calculate a variety of biological metrics and indices.

Throughout the process of exporting data, the original data sources were consulted for any questions or discrepancies that arose. First, the original electronic data files were consulted and proofread to ensure that the data had been migrated correctly from the original format into the EDAS database program. If the conflict could not be resolved in this manner, hard copies of data reports were consulted, or, as necessary, the mining companies and/or the organizations who had originally provided the data were consulted. As data were migrated, Quality Assurance/Quality Control (QA/QC) queries were used to check for import errors. If any mistakes were discovered as a result of one of these QA/QC queries, the entire batch was deleted, re-imported, and re-checked. After all the data from a given source had been migrated, a query was created which duplicated the original presentation of the data. This query was used to check for data manipulation errors. Ten percent of the original samples were checked at random. If the data failed this QC check, they were entirely deleted, re-imported, and subjected to the same QC routine until they were 100% correct.

The EDAS contained separate Master Taxa tables for fish and benthic macroinvertebrates. Both Master Taxa tables contained a unique record for each taxonomic name, along with its associated ecological characteristics (i.e., preferred habitat, tolerance to pollution). To ensure consistency, Master Taxa lists were generated from all of the imported MTM/VF data. Taxonomic names were checked against expert sources, such as Merritt and Cummins (1996), Robins et al. (1991) and the online taxonomic database, Integrated Taxonomic Information System (ITIS, www.itis.usda.gov). Discrepancies and variations in spellings of taxonomic names were identified and corrected in all associated samples. Any obsolete scientific names were updated to the current naming convention to ensure consistency among all the data. Each taxon's associated ecological characteristics were also verified to assure QC for biological metrics generated from that ecological information. Different organizations provided data at different levels of taxonomic resolution. Because the WVSCI utilizes benthic information at the Family level, the benthic macroinvertebrate Master Taxa table was used to collapse all of the data to the Family level for consistency in analysis.

Minimum Detection Limits (MDLs) represent the smallest amount of an analyte that can be detected by a given chemical analysis method. While some methods are very sensitive and, therefore, can detect very small quantities of a particular analyte, other methods are less sensitive and have higher MDLs. When an analytical laboratory is unable to detect an analyte, the value is reported as "Below Detection", and the MDL is given. For the purpose of statistical analysis, the "Below Detection" values were converted to ½ of the methods' MDLs.

3.3. Summary of Analyses

The fish database and the macroinvertebrate database were analyzed separately to: 1) determine if the biological condition of streams in areas with MTM/VF operations is degraded relative to the condition of streams in unmined areas and 2) determine if there are additive biological impacts to streams where multiple valley fills are located. The statistical approach to evaluate these two objectives was the same for fish and macroinvertebrates. To address the first objective, EIS classes (Filled, Filled/Residence, Mined, and Unmined) were compared using one-way analysis of variance (ANOVA). Assumptions for normality and equal variance were assessed using the Shapiro-Wilk Test for normality and Brown and Forsythe's Test for homogeneity of variance. If necessary, transformations were applied to the data to achieve normality and/or stabilize the variance. Significant differences ($p < 0.05$) among EIS classes were followed by the Least Square (LS) Means procedure using Dunnett's adjustment for multiple comparisons to test whether the Filled, Filled/Residence, and Mined EIS classes were significantly different ($p < 0.01$) from the Unmined EIS class. Additive sites from two watersheds were analyzed to evaluate the second objective. Trends in biological condition along the mainstem of Twentymile Creek and Twelvepole Creek were examined using Pearson correlations and regression analysis. Pearson correlations were also used to investigate correlations between biological endpoints and water chemistry parameters. Box plots were generated to display the data across EIS classes and scatter plots were created to show relationships between biological endpoints and chemistry parameters.

3.3.1. Summary of Fish Analysis

Endpoints for the fish analysis were the site averages for the Mid-Atlantic IBI and the site averages for the nine individual metrics that comprise the IBI (Table 1-2). Site averages were used in the analysis since the number of samples taken at a site was inconsistent across sites. Some study sites had been sampled only once, and there were also sites in the database that had been sampled on two or three separate occasions. Mean IBI and component metric values were calculated for all sites sampled multiple times. The mean values were used in all subsequent analyses. Figure 3-1 shows that there was no consistent difference between seasons or years, although there was scatter among observations at some sites. Log-transformed site (geometric) mean chemical concentrations were used as the endpoints for the chemistry analysis.

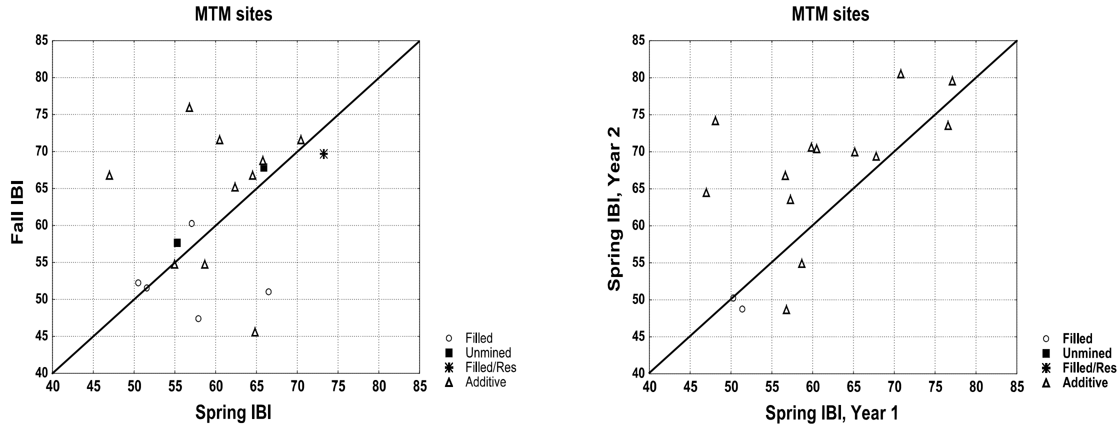


Figure 3-1. Scatter plots showing IBI scores of sites sampled multiple times. The left plot shows autumn samples versus spring samples and the right plot shows spring Year 2 samples versus spring Year 1 samples.

3.3.2. Summary of Macroinvertebrate Analysis

Endpoints for the macroinvertebrate analysis were the WV SCI and its component metrics (Total taxa richness, Ephemeroptera-Plecoptera-Trichoptera [EPT] taxa richness, Hilsenhoff Biotic Index [HBI], % dominant 2 taxa, % EPT abundance, and % Chironomidae abundance). Richness metrics and the WV SCI were rarefacted to 100 organisms to adjust for sampling effort. Comparisons among EIS classes were made for each season (Spring 1999 [April to June], Autumn 1999 [October to December], Winter 2000 [January to March], Spring 2000, Autumn 2000, and Winter 2001). Data for Summer 1999 (July to September) were not compared because of a lack of samples (n= 2) for the Unmined EIS class (i.e., the relative control). Furthermore, in some seasons there were insufficient samples (n < 3) for the Mined and Filled/Residence classes. The WVSCI scores were correlated against key water quality parameters using mean values for each site. Only water chemistry data that were collected at or close to the time of benthos sample collection were used in this analysis.

Habitat data was not evaluated due to the fact that it was not collected consistently and in many cases was collected only once at a site.

4. RESULTS

4.1. Fish Results

4.1.1. IBI Calculation and Calibration

Generally, larger watersheds tend to be more diverse than smaller watersheds (i.e., Karr et al. 1986, Yoder and Rankin 1995). This was found to be true in the MTM/VF study where the smallest headwater streams often had either no fish present or only one or two species present and the large streams had 15 to 27 fish species present (Figure 4-1). To ensure that differences among fish communities were due to differences in stream health and not from the natural effect of watershed size, the three richness metrics (i.e., Native Intolerant Taxa, Native Cyprinidae Taxa and Native Benthic Invertivores) from the Mid-Atlantic Highlands IBI (Section 1.5) were standardized to a 100-km^2 watershed. If the calibration was correct, then there should have been no residual relationship between catchment area and IBI scores. The resultant IBI scores were plotted against catchment area (Figure 4-2) which showed that there was no relationship.

The Mid-Atlantic IBI was not calculated if the catchment area was less than 2.0 km^2. If fewer than ten fish were captured in a sample, then the IBI was set to zero (McCormick et al. 2001). This occurred in six samples. All six of these samples were in relatively small catchments (i.e., 2.0 to 5.0 km^2), where small samples are likely (Figure 4-2). Because small samples may be due to natural factors, these samples were excluded from subsequent analysis..

4.1.2. IBI Scores in EIS Classes

The distributions of IBI scores in each of the EIS classes are shown in Figure 4-3. Distributions of the nine component metrics of the IBI are shown in Appendix B. For comparison, the regional reference sites sampled by the PSU in Big Ugly Creek were also plotted. Figure 4-3 shows that the Filled and Mined classes have lower overall IBI scores than the other EIS classes. The Filled/Residential class had higher IBI scores than any other class. The Filled/Residential class and the Unmined class had median scores that were similar to the regional reference sites. Figure 4-3 shows that more than 50% of the Filled and Mined sites scored “poor” according to the ratings developed by McCormick et al. (2001). Unmined and regional reference sites were primarily in the “fair” range and Filled/Residential sites were mostly in the “good” ranges.

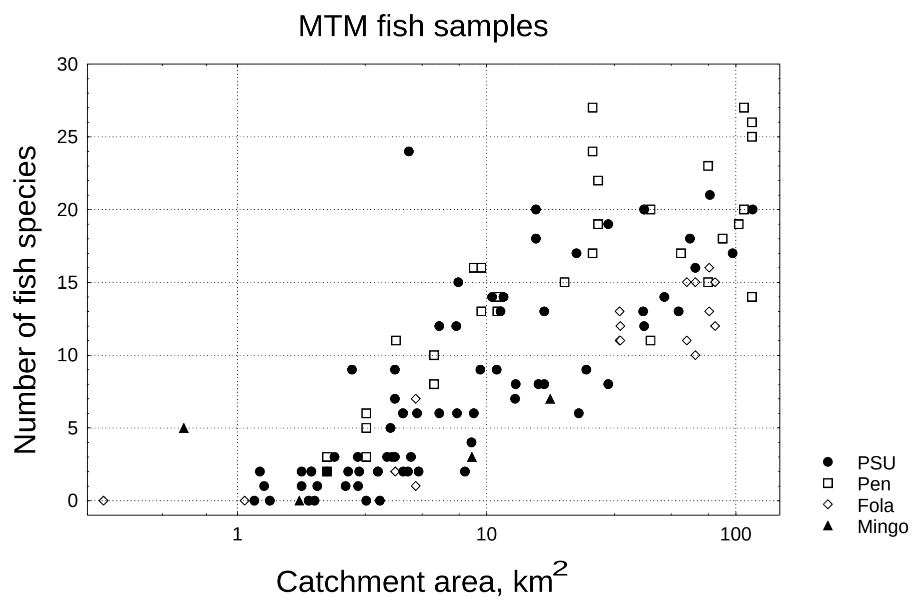


Figure 4-1. Number of fish species captured versus stream catchment area. Symbols identify sampling organizations: PSU=Penn State; Pen = Pen Coal (REIC); Fola = Fola Coal (Potesta); Mingo = Mingo-Logan Coal (BMI).

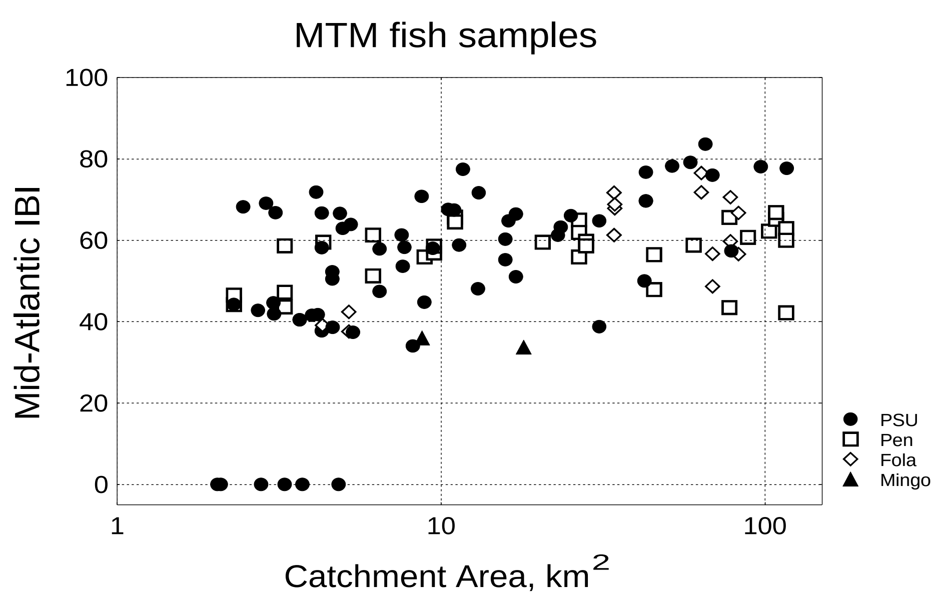


Figure 4-2. Calculated Fish IBI and watershed catchment area, all MTM fish samples from sites with catchment > $2km^2$. Symbols identify sampling organizations: PSU=Penn State; Pen = Pen Coal (REIC); Fola = Fola Coal (Potesta); Mingo = Mingo-Logan Coal (BMI).

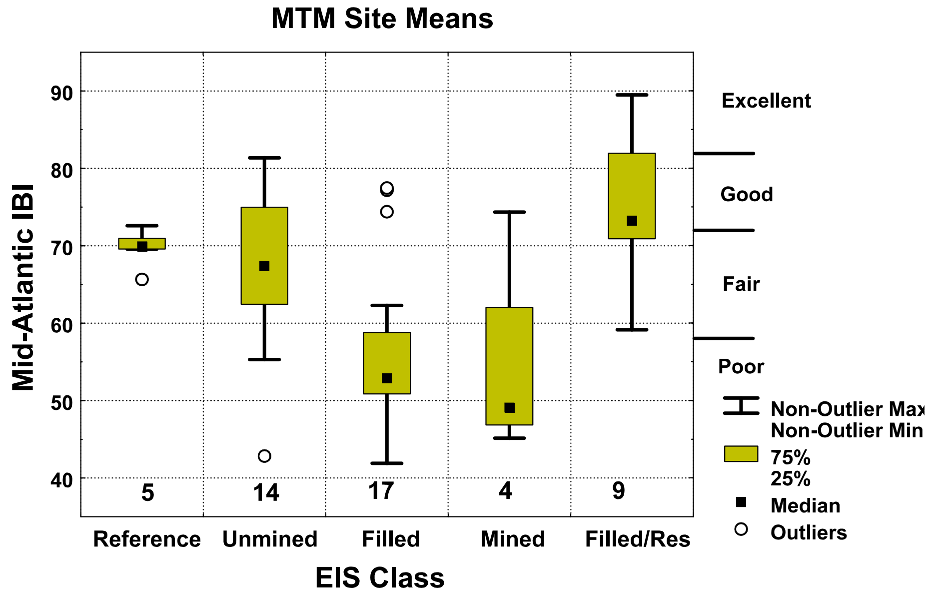


Figure 4-3. A Box-and-Whisker plot of the mean IBI scores from sampling sites in five EIS classes. Catchments less than 2 km^2 and samples with less than ten fish were excluded. Numbers below boxes indicate sample size. Reference sites were the five regional reference sites in Big Ugly Creek, outside of study area. All other sites were in the MTM study area. Assessment categories (McCormick et al.2001) are shown on right side.

A one-way ANOVA was used to test for differences among EIS classes and the LS Means procedure with Dunnett's adjustment was used to compare each class to the Unmined class. The ANOVA showed that differences among the EIS classes were statistically significant (Table 4-1) and the LS Means test showed that the IBI scores from the Filled sites were significantly lower than the IBI scores from the Unmined sites (Table 4-2). The Filled/ Residential class had higher IBI scores than the Unmined sites (Figure 4-3). The IBI scores from Mined sites were lower than the IBI scores from Unmined sites. However, the difference was only marginally significant. This is most likely due to the small sample of Mined sites (n=4). Diagnostics on the IBI analysis indicated that variance was homogeneous and residuals of the model were normally distributed (Figure 4-4 and Appendix B).

The individual metrics that comprise the IBI are not uniform in their response to stressors (McCormick et al. 2001). While some metrics may respond to habitat degradation, other metrics may respond to organic pollution or toxic chemical contamination. Of the nine metrics in the IBI, two (i.e., the number of cyprinid species and the number of benthic invertivore species) were significantly different among the EIS classes. (Appendix B). On average, Filled sites were missing one species of each of these two groups compared to Unmined sites. The third taxa richness metric, Number of Intolerant Species, was not different between Filled and Unmined sites (Appendix B). One additional metric, Percent Tolerant Individuals, showed increased degradation in Filled and Mined sites compared to Unmined sites, on average, but the difference was not statistically significant (Appendix B). Four metrics, Percent Cottidae, Percent Gravel Spawners, Percent Alien Fish and Percent Large Omnivores, were dominated by zero values (Appendix B). Because of the zero values and the resultant non-normal distribution, parametric hypothesis tests would be problematic.

It was concluded from this analysis that the primary causes of reduced IBI values in Filled sites were reductions in the number of minnow species and the number of benthic invertivore species. These two groups of fish are dominant in healthy Appalachian streams. Secondary causes of the reduction of IBI scores in Filled sites are decreased numbers of intolerant taxa, and increased percentages of fish tolerant to pollution. Although Filled sites had IBI scores that were significantly lower than Unmined sites (Table 4-3), several Filled and Mined sites had relatively high IBI scores, similar to regional reference and Unmined sites. In addition, the Filled/Residential sites had higher overall IBI scores. Field crews had observed that there were very few or no residences in the small watersheds of the headwater stream areas. This suggests that the sites where fills and residences were co-located occurred most frequently in larger watersheds and that watershed size may buffer the effects of fills and mines. This possibility was examined and it was found that Filled, Mined, and Filled/Residential sites in watersheds with areas greater than 10 km^2 had fair to good IBI scores. However, Filled and Mined sites in watersheds with areas less than 10 km^2 often had poor IBI scores (Figure 4-5A). Of the 14 sites in watersheds with areas greater than 10 km^2, four were rated fair and ten were rated good or better (Figure 4-5A). Of the 17 sites in watersheds with areas less than 10 km^2, only three rated fair and 14 rated poor (Figure 4-5). In contrast, the control and reference sites showed no overall association with catchment area (Figure 4-5B). The smallest sites (i.e., watershed areas < 3.0 km^2) were highly variable, with three of the five smallest sites scoring poor.

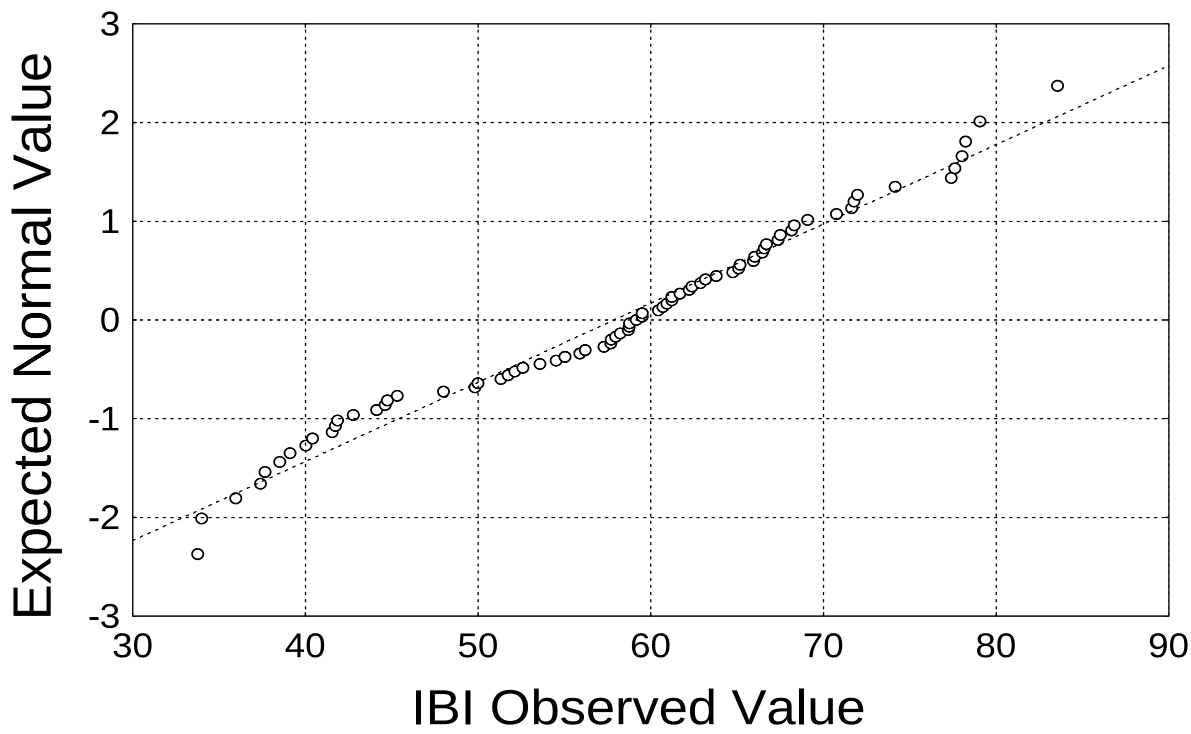


Figure 4-4. Normal probability plot of IBI scores from EIS classes.

Table 4-1. The ANOVA for IBI scores among EIS classes (Unmined, Filled, Mined, and Filled/Residential).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	**3**	**2335.56**	**778.52**	**6.70**	**0.0009**
Error	**40**	**4651.31**	**116.28**		
Corrected Total	**43**	**6986.87**			

R-Square	Coefficient of Variance	Root MSE	Index Mean
0.334	**17.022**	**10.783**	**63.350**

Table 4-2. Dunnett's test comparing IBI values of EIS classes to the Unmined class, with the alternative hypothesis that IBI < Unmined IBI (one-tailed test).

EIS Class	N	Mean	Standard Deviation	Dunnett's P-Value
Filled	**17**	**56.8**	**10.6**	**0.0212**
Filled/Residential	**9**	**74.6**	**10.7**	**0.9975**
Mined	**4**	**54.4**	**13.4**	**0.0685**
Unmined	**14**	**66.7**	**10.3**	**--**

The effect of fills was statistically stronger in watersheds with areas less than 10 km^2 (Table 4-3). Filled sites had an average of one fewer Cyprinidae species, 1.6 fewer benthic invertivore species, 20% more tolerant individuals, and a mean IBI score that is 14 points lower than Unmined sites (Table 4-3). In addition, Intolerant Taxa, % Cottidae and % Gravel Spawners decreased slightly in the filled sites and the % Macro Omnivores increased slightly (Table 4-3). There were too few small Mined sites (n=3) and too few small Filled/Residential sites (n=2) to test against the Unmined sites within the small size category.

There is no definitive test to determine whether the high IBI scores of the Filled/Residential sites in this data set are due solely to large catchment areas or if there may be other contributing factors. The Filled/Residential class is consistent with the relationship observed in the Filled sites, that large catchments are less susceptible to the effects of fills and mines. A definitive test could be conducted if data were collected from several small Filled/Residential catchments.

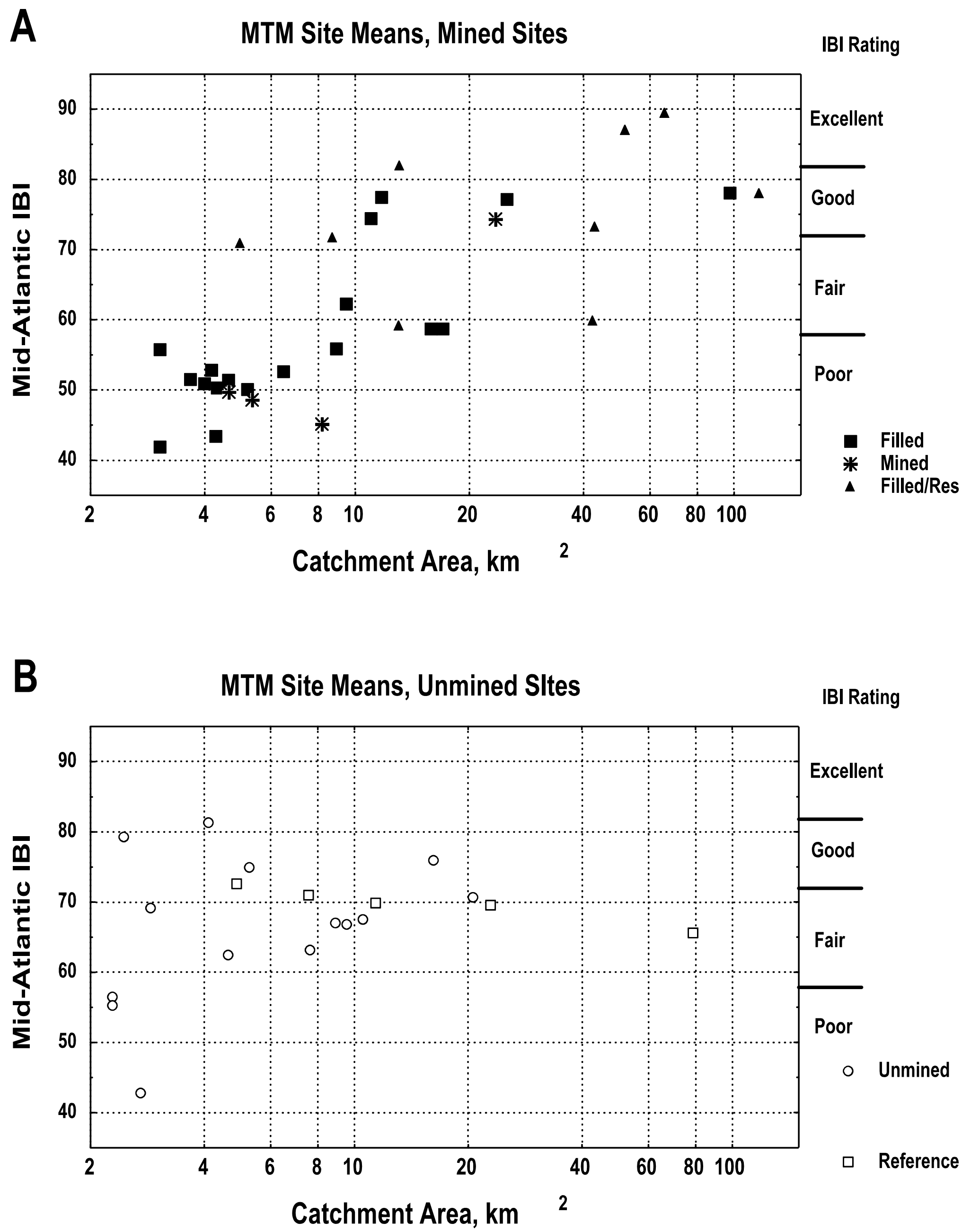


Figure 4-5. The IBI scores for different site classes, by watershed area. Assessment categories (McCormick et al.2001) are shown on right. A) Filled, Mined, and Filled/ Residential sites. B) Unmined and Reference (Big Ugly Creek) sites.

Table 4-3. The results of t-tests of site mean metric values and the IBI in Unmined and Filled sites in watersheds with areas less than 10 km^2 (N = 11 Unmined, N = 12 Filled).

	Mean Unmined	Mean Filled	t-value	p
Cyprinidae Taxa	5.41	4.37	2.93	0.008
Intolerant Taxa	1.03	0.85	1.23	0.232
Benthic Invertivore Taxa	5.80	4.22	3.73	0.001
% Exotic	0.3	0.9	-0.65	0.524
% Cottidae	3.8	0.4	1.42	0.172
% Gravel Spawners	17.2	7.0	0.999	0.329
% Piscivore/Invertivores	34.8	38.8	-0.34	0.739
% Tolerant	71.8	93.8	-2.60	0.0167
% Macro Omnivore	1.4	4.8	-1.54	0.139
IBI	65.4	51.5	3.80	0.001

4.1.3. Additive Analysis

Sites on the mainstem of Twentymile Creek and all mining-affected sites in the Twelvepole Creek watershed have been identified as Additive sites, and were not included in the analysis of the EIS classes reported above. Instead, these sites were considered to be subject to multiple and possibly cumulative sources (i.e., VFs, historic mining, non-point runoff, untreated domestic sewage, non-permitted discharges).

The Twelvepole Creek watershed, in particular, has mixed land uses and has several mining techniques in use. The stream valleys are often populated with residences and livestock. Mining in the Twelvepole watershed includes deep mining, contour mining, and mountaintop removal/VF. In contrast, there is little or no residential land use in the Twentymile Creek watershed and all human activities in the Twentymile Creek are related to mining (i.e., logging and grubbing).

The IBI scores of sites in three streams (i.e., Kiah Creek, Trough Fork, and Twelvepole Creek) in the Twelvepole Creek Watershed are shown in Figure 4-6. Most of the sites are scored in the "fair" range, although a few observations extend into the "good" and "poor" ranges (Figure 4-6). There is no apparent pattern in these scores and there are no trends from upstream to downstream in either of the larger streams (i.e., Kiah Creek and Twelvepole Creek).

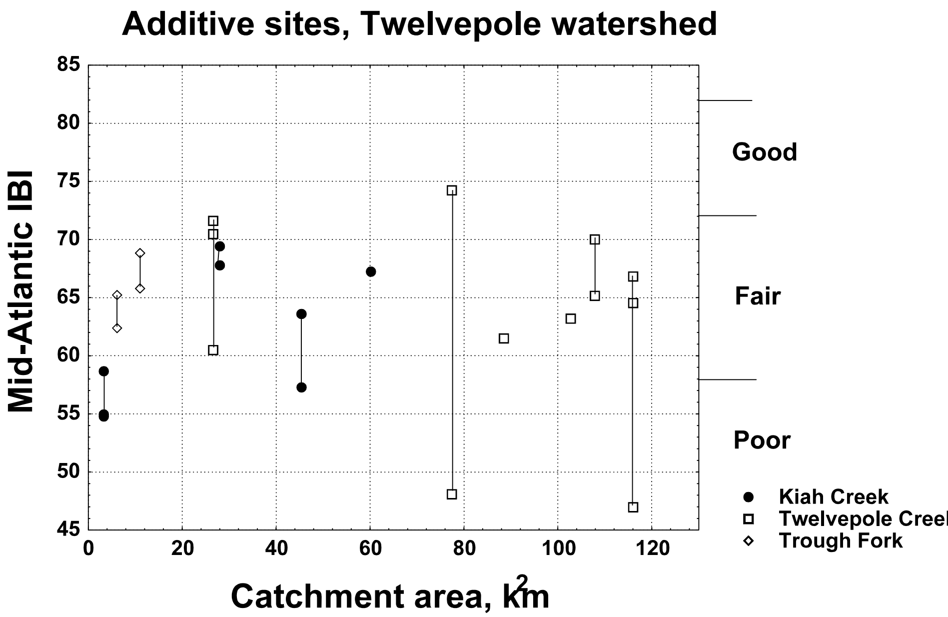
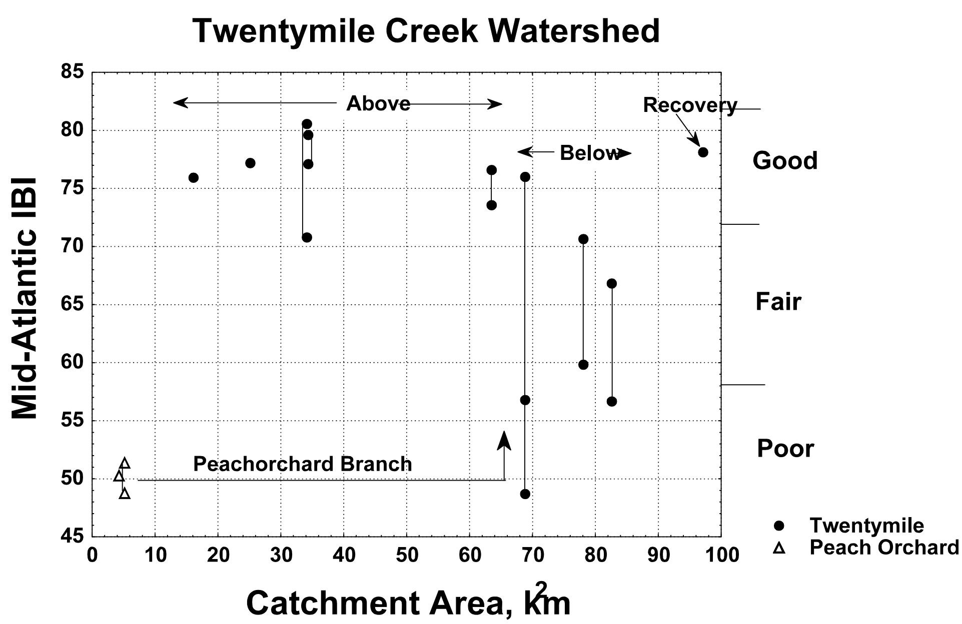


Figure 4-6. The IBI scores from the additive sites in the Twelvepole Creek Watershed. Multiple observations from single sites are connected with a vertical line.

Figure 4-7. IBI scores from additive sites and Peachorchard Branch in the Twentymile



Creek Watershed. Multiple observations from single sites are connected with a vertical line.

Overall, the IBI scores in the Twentymile Creek watershed were higher than those in Twelvepole Creek. There was a trend, from upstream to downstream, among the scores from the Twentymile Creek Watershed (Figure 4-7). Above Peachorchard Branch, which has a catchment area smaller than 68 km^2, sites on the mainstem of Twentymile Creek were uniformly in the "good" range of IBI scores, with moderate variability. Below the confluence of Peachorchard Branch, IBI scores decrease overall and are more variable (Figure 4-7). Farther downstream (i.e., Site PSU.54), the IBI score was higher (i.e., 78), indicating potential recovery from the stressors in the lower portion of the stream. With a range of 48 to 52, Peachorchard Branch had among the lowest IBI scores in the Twentymile Creek Watershed.

4.1.4. Associations With Potential Causal Factors

The correlations between IBI scores and water quality parameters that are potential stressors (i.e., DO, pH, nutrients, TDS, TSS, salts, and metal concentrations) were examined. For the correlation analysis, site mean IBI scores and log-transformed site (geometric) mean chemical concentrations were used. The correlation analysis was restricted to sites in watersheds with areas smaller than 10.0 km^2. The IBI scores decreased with the increased concentrations of several water quality parameters, and decreased significantly with increased zinc and sodium (Table 4-4). However, these correlations do not imply causal relationships between water quality parameters and fish community condition. Other substances or processes associated with mining activity (i.e., erosion, sedimentation), but not measured, could also be proximal causal factors.

Table 4-4. Pearson correlations among the site means of selected water quality measurements and IBI scores, including all sites in watersheds with areas smaller than 10 km^2.

	Log Cr	Log Mg	Log Ni	Log	Log Na	Log SO_4	Log TDS	Log Zn
Log Mg	0.11							
Log Ni	-0.08	0.53						
Log (NO_3+NO_2)	0.40	0.65	0.37					
Log Na	0.16	0.40	-0.08	0.65				
Log SO_4	0.17	0.96	0.43	0.76	0.58			
Log TDS	0.27	0.42	-0.35	0.79	0.90	0.65		
Log Zn	0.50	0.34	0.12	0.47	0.34	0.38	0.42	
IBI	-0.35	-0.42	-0.33	-0.42	-0.60	-0.51	-0.47	-0.54

4.2. Macroinvertebrate Results

4.2.1. Analysis of Differences in EIS Classes

For each season, analyses were conducted to determine if there were any differences among the EIS classes. Only Unmined, Filled, Mined and Filled/Residential sites were used for these analyses. Analysis endpoints were the WVSCI and it's component metrics.

4.2.1.1. Spring 1999

This comparison only used U.S. EPA Region 3 data for each watershed. All of the tested metrics were significantly different among EIS classes using ANOVA, and each met the assumptions for normality and equal variance (Table 4-5). The WVSCI and the taxa richness metrics differed significantly between Unmined sites and both Filled and Filled/Residential sites in the LS Means test. Percent EPT Abundance was also significantly different between Unmined sites and Filled/Residential sites. Box plots for each metric comparison are in Appendix C.

4.2.1.2. Autumn 1999

This comparison used data collected by both the U.S. EPA Region 3 and the private organizations for each watershed. Only the WVSCI, Percent EPT and Percent Chironomidae Abundance were significantly different among EIS classes (Table 4-6). However, the Unmined sites were not significantly different from the other classes for these metrics. Box plots for each metric comparison are in Appendix C. Drought conditions occurred during this season, and streams were further impacted by a severe drought during the preceding summer.

Table 4-5. Results from ANOVA for benthic macroinvertebrates in spring 1999. Uses Unmined sites as a relative control for LS Means test. Total n = 34; Unmined n = 9, Mined n = 4, Filled n = 15, Filled/Residential n = 6.

Metric	p-value	Normality?	Equal Variance?	LS Means
WVSCI (Rarefied to 100 Organisms)	<0.0001	Yes	Yes	Filled and Filled/Residential
Total Taxa (Rarefied to 100 Organisms)	0.0001	Yes	Yes	Filled and Filled/Residential
EPT Taxa (Rarefied to 100 Organisms)	<0.0001	Yes	Yes	Filled and Filled/Residential
HBI	0.0017	Yes	Yes	
Percent Dominant Two Taxa (Arcsine Transformed)	0.0010	Yes	Yes	
Percent EPT Abundance (Arcsine Transformed)	0.0010	Yes	Yes	Filled/Residential
Percent Chironomidae Abundance (Arcsine Transformed)	0.0326	Yes	Yes	

Table 4-6. Results from ANOVA for benthic macroinvertebrates in autumn 1999. Uses Unmined sites as a relative control for LS Means test. Total n = 35, Unmined n = 6, Filled n = 23, Filled/Residence n = 6.

Metric	p-value	Normality?	Equal Variance?	LS Means
WVSCI (Rarefied to 100 Organisms)	0.0454	Yes	Yes	
Total Taxa (Rarefied to 100 Organisms)	0.3744	Yes	Yes	
EPT Taxa (Rarefied to 100 Organisms)	0.2401	Yes	Yes	
HBI	0.1299	Yes	Yes	
Percent Dominant Two Taxa (Arcsine Transformed)	0.2672	Yes	Yes	
Percent EPT Abundance (Arcsine Transformed)	0.0178	Yes	Yes	
Percent Chironomidae Abundance (Arcsine Transformed)	0.0253	Yes	Yes	

4.2.1.3. Winter 2000

This comparison used data collected by both the U.S. EPA Region 3 and the private organizations for each watershed. All of the tested metrics were significantly different among EIS classes, and each met the assumptions for normality (Table 4-7). The WVSCI and the HBI failed the test for equal variance. The WVSCI and the Total Taxa metrics differed significantly between Unmined sites and both Filled and Filled/Residential sites in the LS Means test. Percent EPT abundance was also significantly different between Unmined sites and Filled/Residential sites. Box plots for each metric comparison are in Appendix C.

4.2.1.4. Spring 2000

This comparison used only the data collected by the U.S. EPA Region 3 for each watershed. All of the tested metrics were significantly different among EIS classes, and each met the assumptions for normality (Table 4-8). The WVSCI, EPT Taxa, HBI, and Percent EPT Abundance failed the test for equal variance. The WVSCI and the taxa richness metrics differed significantly between Unmined sites and both Filled and Filled/Residence sites in the LS Means test. Percent EPT abundance in the Unmined sites was also significantly different than in Filled/Residence sites. Box plots for each metric comparison are in Appendix C.

4.2.1.5. Autumn 2000

This comparison used only the data collected by the private organizations for the Twentymile Creek watershed. No metrics were significantly different among EIS classes (Table 4-9). Box plots for each metric comparison are in Appendix C.

4.2.1.6. Winter 2001

This comparison used only the data collected by the private organizations for the Twentymile Creek watershed. The WVSCI, Total Taxa, EPT Taxa, and Percent Dominant 2 Taxa were significantly different among EIS classes (Table 4-10). The Unmined sites were significantly different than the Filled classes for the WVSCI and EPT Taxa, although both metrics failed the equal variance test. Box plots for each metric comparison are in Appendix C.

Table 4-7. Results from ANOVA for benthic macroinvertebrates in winter 2000. Uses Unmined sites as a relative control for LS Means test. Total n = 53, Unmined n = 18, Mined n = 4, Filled n =25, Filled/Residential n = 6.

Metric	p-value	Normality?	Equal Variance?	LS Means
WVSCI (Rarefied to 100 Organisms)	<0.0001	Yes	No	Filled and Filled/Residential
Total Taxa (Rarefied to 100 Organisms)	<0.0001	Yes	Yes	Filled and Filled/Residential
EPT Taxa (Rarefied to 100 Organisms)	<0.0001	Yes	Yes	Filled and Filled/Residential
HBI	<0.0001	Yes	No	
Percent Dominant Two Taxa (Arcsine Transformed)	<0.0001	Yes	Yes	
Percent EPT Abundance (Arcsine Transformed)	<0.0001	Yes	Yes	Filled and Filled/Residential
Percent Chironomidae Abundance (Arcsine Transformed)	<0.0001	Yes	Yes	

Table 4-8. Results from ANOVA for benthic macroinvertebrates in spring 2000. Uses Unmined sites as a relative control for LS Means test. Total n = 35, Unmined n = 10, Mined n = 5, Filled n = 15, Filled/Residence n = 5.

Metric	p-value	Normality?	Equal Variance?	LS Means
WVSCI (Rarefied to 100 Organisms)	0.0001	Yes	No	Filled and Filled/Residential
Total Taxa (Rarefied to 100 Organisms)	0.0004	Yes	Yes	Filled and Filled/Residential
EPT Taxa (Rarefied to 100 Organisms)	<0.0001	Yes	No	Filled and Filled/Residential
HBI	0.0002	Yes	No	
Percent Dominant Two Taxa (Arcsine Transformed)	<0.0001	Yes	Yes	
Percent EPT Abundance (Arcsine Transformed)	0.0027	Yes	No	Filled/Residential
Percent Chironomidae Abundance (Arcsine Transformed)	0.0020	Yes	Yes	

Table 4-9. Results from ANOVA for benthic macroinvertebrates in autumn 2000. Uses Unmined sites as a relative control for LS Means test. Total n = 15; Unmined n = 5, Filled n = 10.

Metric	p-value	Normality?	Equal Variance?	LS Means
WVSCI (Rarefied to 100 Organisms)	0.1945	Yes	Yes	
Total Taxa (Rarefied to 100 Organisms)	0.4744	Yes	Yes	
EPT Taxa (Rarefied to 100 Organisms)	0.1897	Yes	Yes	
HBI	0.7243	Yes	Yes	
Percent Dominant Two Taxa (Arcsine Transformed)	0.0846	Yes	Yes	
Percent EPT Abundance (Arcsine Transformed)	0.3200	Yes	Yes	
Percent Chironomidae Abundance (Arcsine Transformed)	0.4417	Yes	Yes	

Table 4-10. Results from ANOVA for benthic macroinvertebrates in winter 2001. Uses Unmined sites as a relative control for LS Means test. Total n = 16, Unmined n = 6, Filled n = 10.

Metric	p-value	Normality?	Equal Variance?	LS Means
WVSCI (Rarefied to 100 Organisms)	0.0110	Yes	No	Filled
Total Taxa (Rarefied to 100 Organisms)	0.0275	Yes	Yes	
EPT Taxa (Rarefied to 100 Organisms)	0.0074	Yes	No	Filled
HBI	0.4874	Yes	Yes	
Percent Dominant Two Taxa (Arcsine Transformed)	0.0012	Yes	Yes	
Percent EPT Abundance (Arcsine Transformed)	0.3449	Yes	Yes	
Percent Chironomidae Abundance (Arcsine Transformed)	0.1180	Yes	Yes	

4.2.2. Evaluation of Twentymile Creek

Box plots were used to compare benthic macroinvertebrate metrics in the major watersheds during spring 1999, autumn 1999, winter 2000, and spring 2000. Only data from Twentymile Creek was available for autumn 2000 and winter 2001 and it was necessary to examine whether the EIS data collected from the Twentymile Creek Watershed was similar to the EIS data collected from the other four watersheds. Clear Fork could not be used in this watershed analysis, since data for Clear Fork were limited (i.e., there were no Unmined sites and only one Filled site).

No consistent differences in the benthic metrics between the Unmined sites and among watersheds were observed (Appendix C). In contrast, there were consistent differences in the benthic metrics between Filled sites and among watersheds in each season except autumn 1999. Total Taxa, EPT Taxa, Percent EPT Abundance, and the WVSCI were consistently better in Twentymile Creek and Island Creek watersheds than in the Mud River and Spruce Fork watersheds (Appendix C).

4.2.3. Macroinvertebrate and Water Chemistry Associations

The WVSCI scores were correlated against key water quality parameters using mean values for each site. Only water chemistry data that were collected at or close to the time of benthos sample collection were used in this analysis.

The strongest associations were negative correlations between the WVSCI and measures of individual and combined ions (Table 4-11, Appendix D). The WVSCI was also negatively correlated with the metals Beryllium, Selenium, and Zinc.

4.2.4. The Effect of Catchment Area on the WVSCI

The WVSCI and its component metrics had not been evaluated for potential effects related to stream size because of a lack of catchment area data during the original index development. The WVSCI and its component metric scores calculated from the MTM/VF data were plotted against catchment area. A Pearson correlation analysis was also run on these data to investigate whether stream size influenced these scores for the MTM/VF EIS analysis. This analysis was only conducted for the sites in the Unmined EIS class in order to limit any confounding variation due to anthropogenic sources.

There were 20 Unmined sites available for this analysis. However, one site was dropped because catchment area data for that site was unavailable. Because sample size varied greatly

Table 4-11. Results from Pearson correlation analyses between the WVSCI rarefied to 100 organisms and key water quality parameters.

Parameter	n	R	P-value
Alkalinity	53	-0.660	<0.001
Total Aluminum	47	-0.208	0.161
Total Beryllium	52	-0.298	0.032
Total Calcium	53	-0.624	<0.001
Total Chromium	53	-0.043	0.761
Conductivity	53	-0.690	<0.001
Total Copper	53	-0.238	0.086
Hardness	23	-0.650	0.001
Total Iron	49	-0.189	0.193
Total Magnesium	53	-0.569	<0.001
Total Manganese	49	-0.241	0.095
Total Nickel	53	-0.166	0.235
Nitrate/Nitrite	21	-0.362	0.106
DO	60	0.031	0.815
Total Phosphorus	53	-0.165	0.237
Total Potassium	53	-0.527	<0.001
Total Selenium	51	-0.476	<0.001
Total Sodium	53	-0.572	<0.001
Sulfate	53	-0.598	<0.001
Total Dissolved Solids	53	-0.371	0.006
Total Zinc	53	-0.343	0.012

among seasons and was very low in some seasons (i.e., n = 5 or 6), the mean score for each site was used in the analyses.

Neither correlation analyses (Table 4-12) nor scatter plots (Figure 4-8) showed an effect of catchment area on the WVSCI and its metric scores. Analyses with arcsin transformed proportion metrics (i.e., Percent Dominant Two Taxa, Percent EPT Taxa, and Percent Chironomid Taxa) also showed no relationship to catchment area ® = 0.269, -0.144, and 0.090, respectively)

Although no relationship was found, these analyses were limited by the relatively low sample sizes available, and the limited range in catchment area (0.29 – 5.26 km^2) data for Unmined sites. Additional data for larger and relatively undisturbed stream sites within the MTM/VF footprint is necessary to examine stream size effects for the three larger (i.e., area > 40 km^2) Filled/Residence sites. It is unclear whether such sites exist in this area.

Table 4-12. Pearson correlation values and p-values for means of metric scores at Unmined sites (n = 19) versus catchment area.

Metric	R	p-value
Tot_S100	-0.157	0.520
EPT_S100	-0.165	0.501
HBI	0.228	0.348
Dom2Pct	0.255	0.293
EPTPct	-0.168	0.493
ChirPct	0.087	0.724
WVSCI100	-0.312	0.194

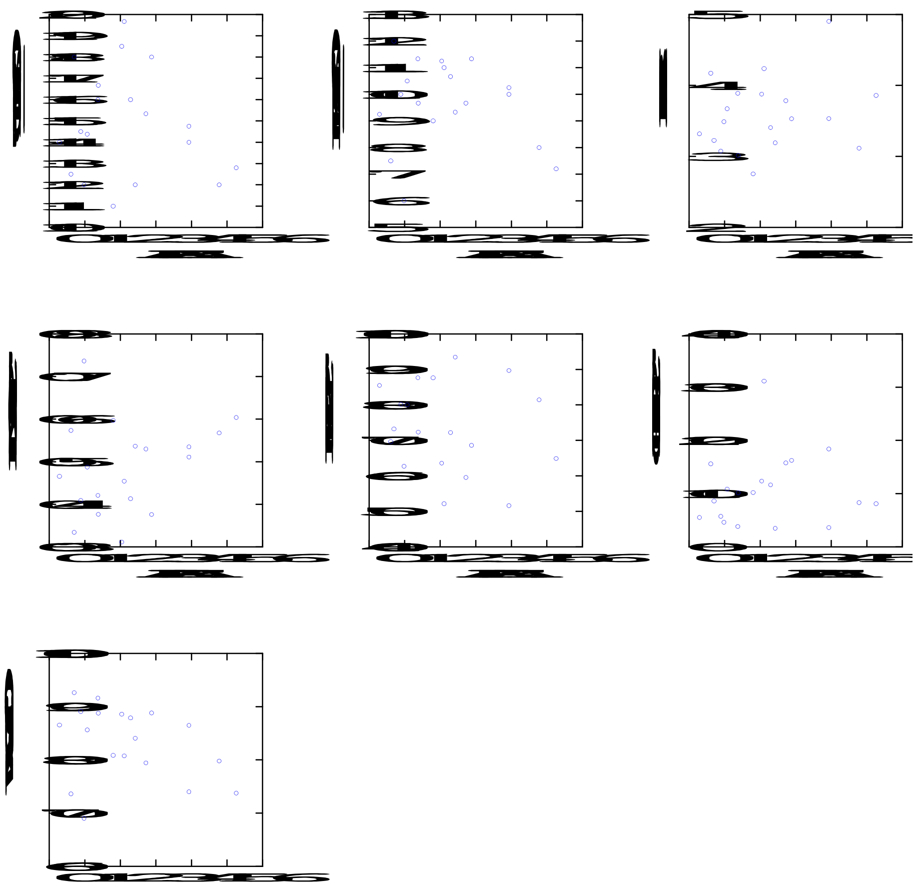


Figure 4-8. The WVSCI and its metric scores versus catchment area in Unmined streams.

4.2.5. Additive Analysis

Multiple sites on the mainstem of Twentymile Creek were identified as Additive sites and were included in an analysis to evaluate impacts of increased mining activities in the watershed across seasons and from upstream to downstream of the Twentymile Creek. Cumulative river kilometer was calculated for each site along Twentymile Creek as the distance from the uppermost site, Rader 8. The total distance upstream to downstream was approximately 17 kilometers. Sites were sampled during four seasons, Autumn 1999 (n = 19), Winter 2000 (n = 23), Autumn 2000 (n = 24) and Winter 2001 (n = 26). Pearson correlations between cumulative river kilometer and the WVSCI and it's component metrics were calculated for each season (Table 4-13). The number of metrics that showed significant correlations with distance along the mainstem increased across seasons. The WVSCI was significantly correlated with cumulative river kilometer in Winter 2000, Autumn 2000 and Winter 2001. In Winter 2001, four of the six individual metrics also showed significant correlations with distance along the mainstem of Twentymile Creek. A linear regression of the WVSCI with cumulative river kilometer indicated that the WVSCI decreased approximately one point upstream to downstream for every river kilometer (Table 4-14).

Table 4-13. Pearson correlation values and p-values for metric scores at Additive sites on Twentymile Creek versus cumulative river kilometer by season.

Metric	Autumn 1999	Winter 2000	Autumn 2000	Winter 2001
Tot_S100	-0.582 (0.009)	0.051 (0.8169)	-0.670 (<.001)	-0.462 (0.018)
EPT_S100	-0.480 (0.038)	-0.230 (0.196)	-0.688 (<.001)	-0.593 (0.002)
HBI	-0.210 (0.387)	-0.227 (0.296)	-0.228 (0.284)	0.410 (0.037)
Dom2Pct	0.360 (0.130)	0.521 (0.011)	0.626 (0.001)	0.545 (0.004)
EPTPct	0.018 (0.940)	-0.004 (0.986)	0.145 (0.499)	-0.235 (0.248)
ChirPct	-0.075 (0.759)	-0.377 (0.076)	-0.048 (0.824)	0.091 (0.658)
WVSCI100	-0.353 (0.138)	0.762 (<.001)	-0.627 (0.001)	-0.608 (0.001)

Table 4-14. The Regression for WVSCI versus Cumulative River Mile for Additive Sites in Twentymile Creek Winter 2001.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	658.99	658.99	14.05	0.0010
Error	24	1125.55	46.90		
Corrected Total	25	1784.54			

R-Square	Coefficient of Variance	Root MSE	WVSCI Mean
0.369	8.27	6.848	82.80

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	92.66	2.95	31.38	<.0001
Cumulative River Km	-1.14	0.30	-3.75	0.001

5. DISCUSSION AND CONCLUSIONS

5.1. Fish Discussion and Conclusions

From the analysis of the fish data among the EIS classes, it was determined that IBI scores were significantly reduced in streams below VFs, compared to unmined streams, by an average of 10 points, indicating that fish communities were degraded below VFs. The IBI scores were similarly reduced in streams receiving drainage from historic mining or contour mining, compared to unmined streams. Nearly all filled and mined sites with catchment areas smaller than 10.0 km^2 had “poor” IBI scores, whereas filled and mined sites with catchment areas larger than 10.0 km^2 had “fair” or “good” IBI scores. In the small streams, IBI scores from Filled sites were an average of 14 points lower than the IBI scores from Unmined sites. Most Filled/Residential sites were in larger watersheds (i.e., areas > 10.0 km^2), and Filled/Residential sites had “fair” or “good” IBI scores.

From the additive analysis, it was determined that the Twelvepole Creek Watershed, in which the land use was mixed residential and mining, had “fair” IBI scores in most samples, and there are no apparent additive effects of the land uses in the downstream reaches of the watershed. Also, Twentymile Creek, which has only mining-related land uses, has “Good” IBI scores upstream of the confluence with Peachorchard Creek, and “Fair” and “Poor” scores for several miles downstream of the confluence with Peachorchard Creek tributary. Finally, Peachorchard Creek has “Poor” IBI scores, and may contribute contaminants or sediments to Twentymile Creek, causing degradation of the Twentymile IBI scores downstream of Peachorchard Creek.

5.2. Macroinvertebrate Discussion and Conclusions

The results of the macroinvertebrate analyses showed significant differences among EIS classes for the WVSCI and some of its component metrics in all seasons except autumn 2000. Differences in the WVSCI were primarily due to lower Total Taxa, especially for mayflies, stoneflies, and caddisflies, in the Filled and Filled/Residential EIS classes.

Sites in the Filled/Residential EIS class usually scored the worst of all EIS classes across all seasons (Appendix C). It was not determined why the Filled/Residential class scored worse than the Filled class alone. U.S. EPA (2001 Draft) found the highest concentrations of Na in the Filled/Residential EIS class, which may have negatively impacted these sites compared to those in the Filled class.

When the results for Filled and Unmined sites alone were examined, significant differences were observed in all seasons except autumn 1999 and autumn 2000. This can be seen in the plots of the WVSCI, Total Taxa, and EPT Taxa versus season (Figures 5-1, 5-2a and

5-2b). The lack of differences between Unmined and Filled sites in autumn 1999 was due to a decrease in Total Taxa and EPT Taxa in Unmined sites relative to a lack of change in Filled sites. These declines in taxa richness metrics in Unmined sites was likely a result of the drought conditions of the summer 1999, which caused more Unmined sites to go dry or experience severe declines in flow relative to Filled sites (Green et al., 2000). Wiley et al. (2001) also found that Filled sites have daily flows that are greater than those in Unmined sites during periods of low discharge. Despite the relatively drier conditions in Unmined sites during autumn 1999, WVSCI scores and EPT Taxa richness increased in later seasons to levels seen in the spring 1999 season whereas values for Filled sites stayed relatively low.

The lack of statistical differences between Unmined and Filled classes in the autumn 2000 appears to be due to a decline of Total Taxa richness in Unmined sites coupled with an increase in Total Taxa richness in Filled sites (Figures 5-1, 5-2 and 5-3). Filled sites had higher variability in WVSCI scores and metric values than did Unmined sites during the autumn 2000, which also contributed to the lack of significant differences. It is important to note that this comparison only uses data from the Twentymile Creek Watershed. Hence, the lack of differences in metrics during the autumn 2000 between Unmined and Filled sites is only relevant for the Twentymile Creek watershed, and not the entire MTM/VF study area examined in the preceding seasons. Similarly, data for winter 2001 is only representative of the Twentymile Creek watershed, but it is noteworthy that these data did show that Unmined and Filled sites were significantly different. It was also found that Filled sites in the Twentymile Creek Watershed scored better than filled sites in the Mud River and Spruce Fork Watersheds in all seasons except for autumn 1999. These differences among watersheds indicate biological conditions in Filled sites of the Twentymile Creek watershed are not representative of the range of conditions in the entire MTM/VF study area. As a result, comparisons among EIS classes during autumn 2000 and winter 2001 should not be considered typical for the entire MTM/VF study area.

Statistical differences between the Unmined and Filled EIS classes corresponded to ecological differences between classes based on mean WVSCI scores. Unmined sites scored in the Very Good condition category in all seasons except autumn 1999 when the condition was scored as Good. The conditions at Filled sites ranged from Fair to Good (Figure 5-1). However, Filled sites that scored Good on average only represented conditions in the Twentymile Creek watershed in two seasons (i.e., autumn 2000 and winter 2001), and these sites are not representative of the entire MTM/VF study area. On average Filled sites were in worse ecological condition than were Unmined sites.

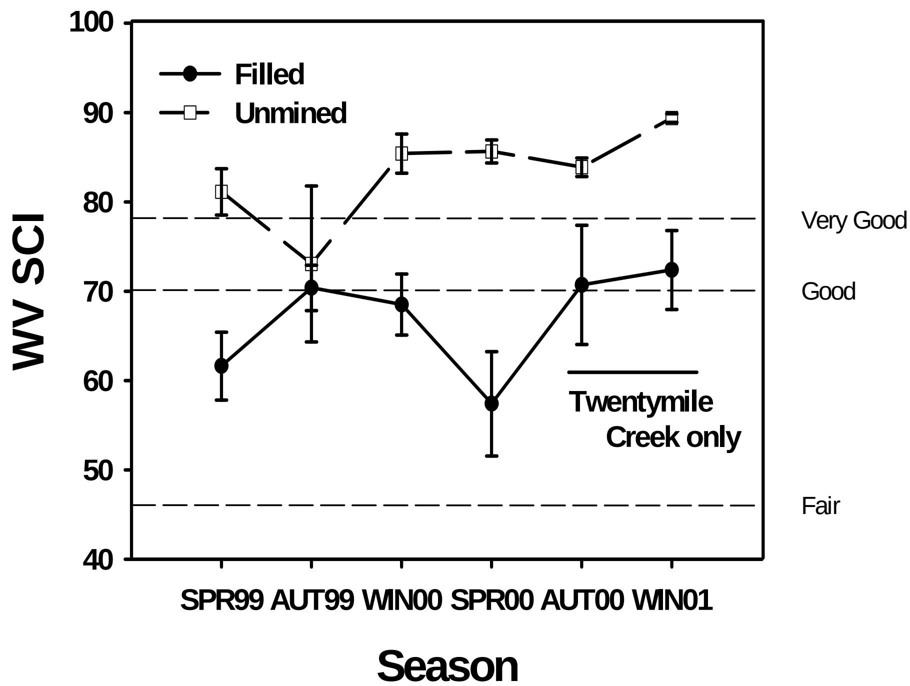


Figure 5-1. Mean WVSCI scores in the Unmined and Filled EIS classes versus sampling season. Error bars are 1 SE. Data for autumn 2000 and winter 2001 only used private organization data for the Twentymile Creek Watershed. The condition categories are based on Green et al. (2000 Draft).

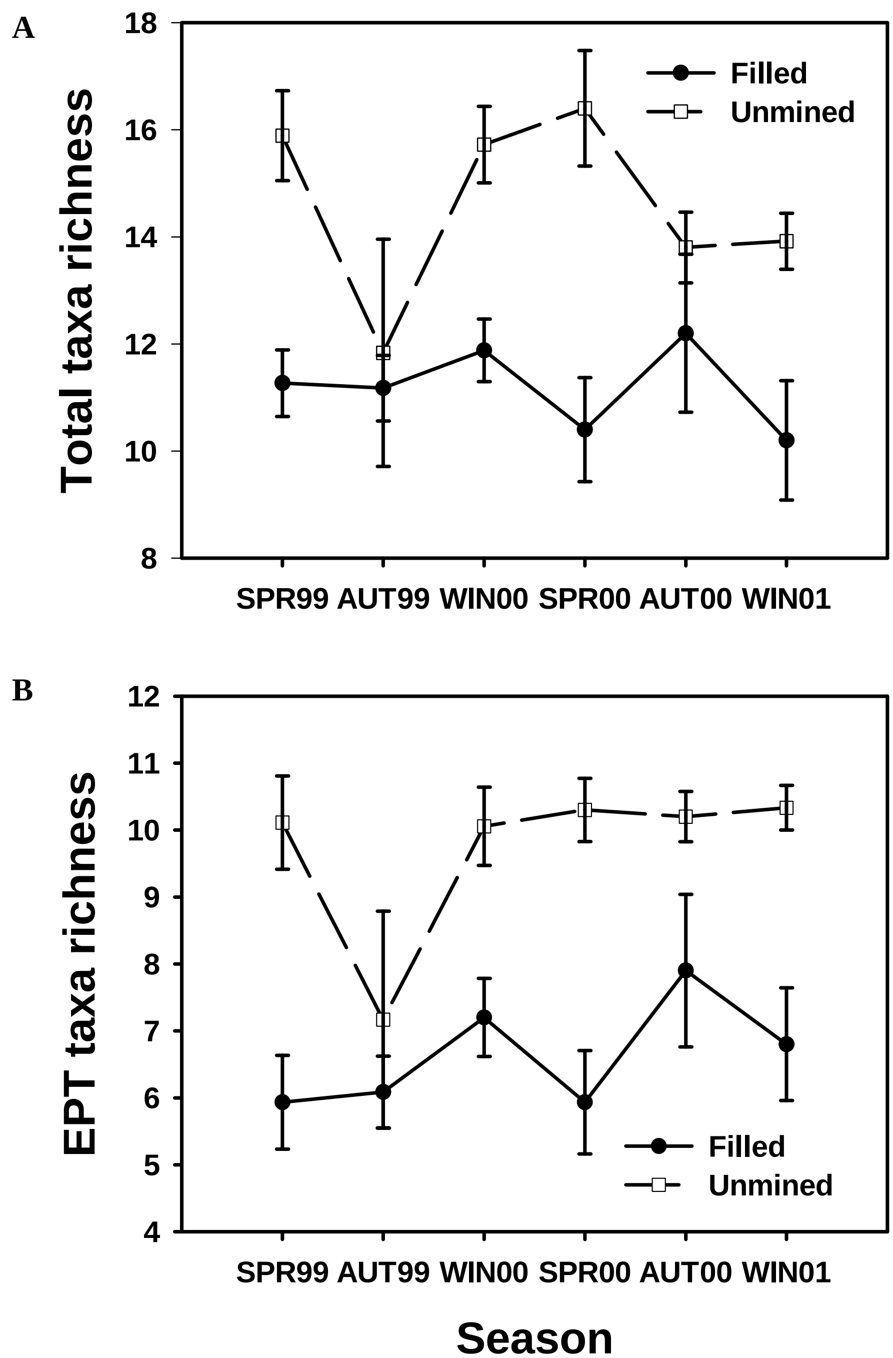


Figure 5-2. (A) Mean Total Taxa richness in the Unmined and Filled EIS classes versus sampling season. (B) Mean EPT Taxa richness in the Unmined and Filled EIS classes versus sampling season. Error bars are 1 SE. Data for autumn 2000 and winter 2001 only used private organization data for the Twentymile Creek Watershed.

The consistently higher WVSCI scores and the Total Taxa in the Unmined sites relative to Filled sites across six seasons showed that Filled sites have lower biotic integrity than those sites without VFs. Furthermore, reduced taxa richness in Filled sites is primarily the result of fewer pollution-sensitive EPT taxa. The lack of significant differences between these two EIS classes in autumn 1999 appears to be due to the effects of greatly reduced flow in sites draining unmined sites during a severe drought. Continued sampling in Unmined and Filled sites would improve the understanding of whether MTM/VF activities are associated with seasonal variation in benthic macroinvertebrate metrics and base-flow hydrology.

Examination of the Additive sites from the mainstem of Twentymile Creek indicated that impacts to the benthic macroinvertebrate communities increased across seasons and upstream to downstream of Twentymile Creek. In the first sampling season one metric, Total Taxa, was negatively correlated with distance along the mainstem. The number of metrics showing a relationship with cumulative river mile increased across seasons, with four of the six metrics having significant correlations in the final sampling season, Winter 2001. Also in Winter of 2001, a regression of the WVSCI versus cumulative river kilometer estimates a decrease of approximately one point in the WVSCI for each river kilometer. Season and cumulative river kilometer in this dataset may be surrogates for increased mining activity in the watershed.

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APPENDIX A

SUMMARY TABLES OF PROTOCOLS AND PROCEDURES USED BY THE FOUR ORGANIZATIONS TO COLLECT DATA FOR THE MTM/VF STUDY

Table A-1. Habitat assessment procedures used by the four organizations participating in the MTM/VF Study.

Habitat Assessment Procedures				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Site Selection Criteria	The watershed to be assessed began at least one receiving stream downstream of the mining operation and extended to the headwaters. Monitoring stations were positioned downstream in a similar watershed representative of the future impact scenario. Where possible, semi-annual samples were taken where baseline data were collected. Following Phase II, but prior to final release, samples to be taken where mining phase data were collected. See benthic macroinvertebrate procedures for further details.	No information on habitat data collection given.	Based on agreement reached between the client and regulatory agencies. Sites were selected to provide quantitative, site specific identification and characterization of sources of point and non-point chemical contamination.	No information on habitat data collection given.
Methods Used	Habitat assessment made according to Barbour et al. (1999). Riparian habitat and substrate described using Kaufmann and Robison (1998). Habitat assessment is made as a part of the benthic macroinvertebrate survey.	No information on habitat data collection given.	Habitat assessments performed at the same reach from which biological sampling was conducted. Used the protocols in Kaufmann and Robison (1998) or Barbour et al. (1999).	No information on habitat data collection given.
Procedures	A habitat assessment made according to Barbour et al. (1999) and the riparian habitat and substrate described using Kaufmann and Robison (1998).	No information on habitat data collection given.	A single habitat assessment form which incorporated the features of the sampling reach and of the catchment area was completed. Habitat evaluations were made first on instream habitat, followed by channel morphology, bank structural features and riparian vegetation.	No information on habitat data collection given.

(Continued)

Table A-1. Continued.

Habitat Assessment Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Habitat QA/QC	A habitat assessment made according to Barbour et al. (1999) and the riparian habitat and substrate described using Kaufmann and Robison (1998).	No information on habitat data collection given.	Accepted QA/QC practices were employed during habitat assessment. The habitat evaluations were conducted by a trained field biologist immediately following the biological and water quality sampling. The completed habitat assessment form was reviewed by a second field biologist before leaving the sampling reach. The biologists discussed the assessment. Photographs of the sampling reaches were collected and used as a basis for checks of the assessments. The habitat data were entered into a database, then they were checked against the field sheets.	No information on habitat data collection given.

Table A-2. Parameters and condition categories used in the U.S. EPA's RBP for habitat.

RBP Habitat Parameter	Condition Category			
	Optimal	**Sub-optimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover **(high and low gradient)**	Greater than 70% (50% for low gradient streams) of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/ snags that are not new fall and not transient).	40-70% (30-50% for low gradient streams) mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of new fall, but not yet prepared for colonization (may rate at high end of scale).	20 - 40% (10-30% for low gradient streams) mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% (10% for low gradient streams) stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness **(high gradient)**	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regimes **(high gradient)**	All four velocity/depth regimes present (slow-deep, slow- shallow, fast-deep, fast-shallow). (Slow is <0.3 m/s, deep is >0.5 m).	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition **(high and low gradient)**	Little or no enlargement of islands or point bars and less than 5% (<20% for low-gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition f new gravel, sand or fine sediment on old and new bars; 30-50% 50-80% for low-gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status **(high and low gradient)**	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

(Continued)

Table A-2 (Continued).

6. Channel Alteration **(high and low gradient)**	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization (i.e., dredging, greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. In-stream habitat greatly altered or removed entirely.
SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**
7. Frequency of Riffles (or bends) **(high gradient)**	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuos, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 and 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 and 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**
8. Bank Stability (score each bank) **(high and low gradient)**	Banks stable: evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE_____ LB	**Left Bank 10 9**	**8 7 6**	**5 4 3**	**2 1 0**
SCORE_____ RB	**Right Bank 10 9**	**8 7 6**	**5 4 3**	**2 1 0**
9. Bank Vegetative Protection **(score each bank)** **(high and low gradient)**	More than 90% of the stream bank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the stream bank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the stream bank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one half of the potential plant stubble height remaining.	Less than 50% of the stream bank surfaces covered by vegetation; disruption of stream bank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE_____ LB	**Left Bank 10 9**	**8 7 6**	**5 4 3**	**2 1 0**
SCORE_____ RB	**Right Bank 10 9**	**8 7 6**	**5 4 3**	**2 1 0**

(Continued)

Table A-2 (Continued).

10. Riparian Vegetation Zone Width (score each bank riparian zone) **(high and low gradient)**	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE_____ LB	**Left Bank 10 9**	**8 7 6**	**5 4 3**	**2 1 0**
SCORE_____ RB	**Right Bank 10 9**	**8 7 6**	**5 4 3**	**2 1 0**

Table A-3. Substrate size classes and class scores.

Class	Size	Class Score	Description
Bedrock	> 4000 mm	6	Bigger than a car
Boulder	250 to 4000 mm	5	Basketball to car
Cobble	64 to 250 mm	4	Tennis ball to basketball
Coarse Gravel	16 to 64 mm	3.5	Marble to tennis ball
Fine Gravel	2 to 16 mm	2.5	Ladybug to marble
Sand	0.06 to 2 mm	2	Gritty between fingers
Fines	< 0.06 mm	1	Smooth, not gritty

Table A-4. Water quality assessment procedures used by the four organizations participating in the MTM/VF Study.

Water Quality Procedures				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Site Selection Criteria	The watershed to be assessed began at least one receiving stream downstream of the mining operation and extended to the headwaters. Monitoring stations were positioned downstream in a similar watershed representative of the future impact scenario. Where possible, semi-annual samples were taken where baseline data were collected. Following Phase II, but prior to final release, samples to be taken where mining phase data were collected. See benthic macroinvertebrate procedures for further details.	No information on water quality assessment given.	Based on agreement reached between the client and regulatory agencies. Sites were selected to provide quantitative, site specific identification and characterization of sources of point and non-point chemical contamination.	Not specified in Comprehensive QA Plan.
Methods Used to Make Water Quality Measurements in the Field	Stream flow was measured. Temperature, pH, DO, and conductivity were also measured.	No information on water quality assessment given.	Stream flow was measured at or near the sampling point using techniques in Kaufmann (1998). The data were recorded on a field form. Temperature, pH, DO and conductivity measurements were made using protocols in U.S. EPA (1983). These parameters were measured *in situ* at all sites and recorded on field sheets. The measurements were made directly upstream of the biological sampling site.	Characteristics (i.e., size, depth and flow) and site location are recorded.

(Continued)

Table A-4. Continued.

Water Quality Procedures (Continued)				
	U.S, EPA Region 3	**BMI**	**POTESTA**	**REIC**
Sample Collection	Samples were collected in accordance with Title 40, Chapter I, Part 136 of the Code of Federal Regulations.	No information on water quality assessment given.	Field personnel collected grab samples at each station in conjunction with and upstream of benthic macroinvertebrate sampling events. Water samples were labeled in the field. Samples were collected in accordance with Title 40, Chapter I, Part 136 of the Code of Federal Regulations.	Grab samples are collected with a transfer device or with the sample container. Transfer devices are constructed of inert materials. Samples are placed in appropriate containers. Samples are labeled in the field.
Preservation	Samples were preserved in accordance with Title 40, Chapter I, Part 136 of the Code of Federal Regulations.	No information on water quality assessment given.	Samples were preserved in the field	Samples are preserved in the field. Samples are placed in temperature controlled coolers (4º C) immediately after sampling
Laboratory Transfer	No guidance on water sample transport given.	No information on water quality assessment given.	Samples were transferred to a state-certified laboratory for analysis. Chain-of-custody forms accompanied samples to the laboratory.	Samples are delivered to the laboratory as soon as possible. A chain-of-custody record accompanies each set of samples.

(Continued)

Table A-4. Continued.

Water Quality Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Parameters Analyzed in the Laboratory	Recommended Parameters: dissolved iron dissolved manganese dissolved aluminum calcium magnesium sodium potassium chloride total suspended solids total dissolved solids alkalinity acidity sulfate dissolved organic carbon hardness nitrate/nitrite total phosphorous	No information on water sample analyses given.	alkalinity acidity total suspended and dissolved solids sulfate nitrate/nitrite total phosphorus chloride sodium potassium calcium magnesium hardness total iron total and dissolved manganese total and dissolved aluminum total antimony total arsenic total beryllium total cadmium total chromium total copper total lead total mercury total nickel total selenium total silver total thallium total zinc coarse particulate organic matter fine particulate organic matter total organic carbon	Not specified for this project in the QA Plan.
General QA/QC	A QA/QC plan should be developed.	No information on water chemistry QA/QC practices given.	Accepted QA/QC practices are employed during sampling and analysis.	QA/QC practices are detailed in REI Consultants, Inc. (2001).

(Continued)

Table A-4. Continued.

Water Quality Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Field QA/QC	A QA/QC plan should be developed.	No information on water chemistry QA/QC practices given.	Temperature, pH, DO and conductivity measurements are made using protocols in U.S. EPA (1983). Dissolved oxygen and pH meters are calibrated daily. Calibrations are checked after unusual readings and adjusted if needed. All probes are thoroughly rinsed with distilled water after all calibrations and between sampling sites.	No information on field measurement QA/QC practices given.
Sample Collection QA/QC	A QA/QC plan should be developed.	No information on sample collection QA/QC practices given.	All containers and lids are new. All containers, preservatives and holding times meet the requirements given in Title 40 (Protection of the Environment), Part 136 (Guidelines Establishing Test Procedures for the Analysis of Pollutants) of the Code of Federal Regulations. Each container is labeled with the site identification, date and preservative. Chain-of custody forms are filled out for each group of samples and accompany the samples to a state-certified laboratory.	No information on sample collection QA/QC practices given.
Laboratory QA/QC	A QA/QC plan should be developed.	No information on water sample analysis laboratory QA/QC practices given.	The laboratory analysis of water chemistry follows Standard Methods and/or EPA approved methods. Any deviations from these methods are noted.	No information on water sample analysis laboratory QA/QC practices given.

Table A-5. Fish assemblage assessment procedures used by the four organizations participating in the MTM/VF Study.

Fish Procedures				
	U.S. EPA Region 3 (PSU)	**BMI**	**POTESTA**	**REIC**
Site Selection Criteria	At least one site was established at the most downstream extent of the impact area. This site was permanently recorded and revisited annually. See benthic macroinvertebrate procedures for further details.	No information on fish data collection given.	Sites were designated in consultation with regulatory agencies.	1) Within vicinity of macroinvertebrate and water quality sampling locations. 2) Reaches contained variety of habitat, cover, water velocities and depths. 3) Representative of the stream. 4) If bracketing a confluence, were as close to the tributary as possible, while allowing a downstream buffer for mixing. 5) If used for comparative purposes, contained similar amounts of fish habitat and cover and frequency of riffles and pools.
Station Preparation	Protocols generally followed those in McCormick and Hughes (1998). The stream reach was 40 times the wetted width of the stream, with a maximum reach of 150 m.	No information on fish data collection given.	Stream reach lengths were at least 40 times the stream width and did not exceed 150m.	A stream reach of 150 m was used. Block nets of ⅛-in mesh were set perpendicular to stream by approaching from the shore. Nets were set tight against the substrate and remained in place throughout the survey.
Electrofishing Procedures	Protocols generally followed those in McCormick and Hughes (1998). Block nets were set at the ends of the reach. Amps, voltage and pulse were set according to the stream's conductivity. The surveys began at the downstream end of the reach and proceeded upstream. Netters retrieved the fish and placed them in buckets. The fish were processed at the end of each transect. The survey proceeded until all transects had been fished.	No information on fish data collection given.	Fish were collected at each site using a backpack electrofishing unit. Collections began at the downstream end of the reach and proceeded upstream for the entire reach. Fish collected during the first pass were placed in a bottle labeled "Collection #1". Two additional passes were made and fish from the second and third pass were placed in bottles labeled "Collection #2" and "Collection #3, respectively. If the number of fish in the latter passes did not decline from the previous pass, additional passes were made.	Surveys were conducted in first-, second- and third-order streams by a backpack electrofishing unit. The output voltage and pulse frequency were controlled by the biologist. The biologist progressed slowly upstream moving the wands across the entire stream width. Technicians positioned on each side of the biologist netted the stunned fish and placed them in buckets containing water. Three passes were conducted at each station.

(Continued)

Table A-5. Continued.

Fish Procedures (Continued)				
	U.S. EPA Region 3 (PSU)	**BMI**	**POTESTA**	**REIC**
Field Measurements	Fish were identified, tallied and examined for external anomalies. The standard length of each fish was measured to the nearest mm and each fish was weighed to the nearest 0.01 g.	No information on fish data collection given.	Fish from each pass were kept separate. Game fish (except small specimens) and rare, threatened or candidate species were counted, measured (total length), weighed and released. These data were recorded on field sheets. The majority of fish captured were preserved in 10% formalin and taken to the laboratory. Each collection was preserved separately.	After each pass, fish were identified, measured to the nearest mm of total length and weighed to the nearest 0.1 gm or 1.0 gm (depending on fish size). Large fish were held in a live well until the completion of the survey, then released to their original reach. Small fish requiring microscopic verification were preserved in 10% formalin and taken to the laboratory.
Specimen Preparation, Identification and Validation	Fish were labeled and preserved in 10% formalin and transported to the PSU Fish Museum where they were deposited for permanent storage in 50% isopropanol. Voucher collections of up to 25 individuals of each taxon collected (except very large individuals of easily identified species) were prepared.	No information on fish data collection given.	Preserved specimens were taken to the laboratory and temporarily stored in 50% isopropanol or 10% ethanol. They were identified and weighed. All preserved fish were placed in permanent storage in a recognized museum collection or offered for use in the federal EIS on MTR/VF mining in West Virginia.	Small fish were identified in the laboratory. All fish were sorted by species and their identities were verified when they were weighed to the nearest 0.1 gm and their total lengths were measured. Identified fish were stored. Unidentified fish were identified and validated by West Virginia DNR personnel.
Fish Data Analysis	Total biomass caught, biomass per m^2 sampled and abundances of each species were calculated.	No information on fish data analysis given.	Fish data sheets were transferred into spreadsheets. Data entered into the spreadsheets were routinely checked against field and laboratory sheets immediately following data entry. Any discrepancies were documented and corrected. Population and community structure were determined at each site. Age classes based on length, frequency analysis and standing crop (kg/ha) were calculated for each species at each pass.	Data were entered into a spreadsheet and confirmed. At each sampling station, total taxa, number and percent of pollution-intolerant fish, number and percent of intermediately pollution- tolerant fish, Number and percent of pollution-tolerant fish, Shannon-Weiner diversity Index, Percent species similarity index were made. For each species at each sampling station, Total abundance, Mean length, Mean weight, Standing stock, and Sensitivity index (U.S. EPA 1999) were calculated.

(Continued)

Table A-5. Continued.

Fish Procedures (Continued)				
	U.S. EPA Region 3 (PSU)	**BMI**	**POTESTA**	**REIC**
Fish Population Estimates	No information on fish population estimates given.	No information on fish data analysis given.	Population estimates of each species at each site were made using the triple pass depletion method of Van Deventer and Platts (1983).	Population estimates for each species and each reach were calculated using the Zippin (1956) depletion method and based on observed relative abundance. Total fish weight by species was extrapolated to calculate an estimated total standing stock.
Fish Identification and Verification QA/QC	The interim protocols stated that a QA/QC plan should be developed.	No information on fish data QA/QC given.	Implemented the QA/QC plan from the U.S. Geological Survey (Walsh and Meador 1998). The plan outlines methods used to ensure accurate identification of fish collected. A voucher collection including one specimen of each taxon collected was made available for verification. Data entered into spreadsheets were routinely checked against field and laboratory sheets.	The QA/QC protocols called for the use of two Fisheries Biologists with the appropriate qualifications: Any species captured whose distribution did not match Stauffer et al. (1995) was recorded and the identification was confirmed by West Virginia DNR personnel. All identifications were confirmed by both Fisheries Biologists. Small fish which required microscopic identification were stored for future reference or identification. A reference collection of all captured taxa was kept. Any species of questionable identification were kept and verified by West Virginia DNR personnel. All retained specimens were permanently labeled.

Table A-6. Macroinvertebrate assemblage assessment procedures used by the four organizations participating in the MTM/VF Study.

Benthic Macroinvertebrate Procedures				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Site Selection Criteria	The watershed to be assessed began at least one receiving stream downstream of the mining operation and extended to the headwaters. Monitoring stations were positioned downstream in a similar watershed representative of the future impact scenario. Where possible, semi-annual samples were taken where baseline data were collected. A minimum of two stations were established for each intermittent and perennial stream where fills were proposed. One station was as close as possible to the toe of the fill and the other was downstream of the sediment pond location. If the sediment pond was more than 0.25 mi from the toe of the fill, a third station was placed between the two. Additional stations were placed in at least the first receiving stream downstream of the mining operation.	BMI located one sampling station as close as possible to the toe of the proposed VF. Another sampling station was located below the proposed sediment pond. If the proposed sediment pond was to be > 0.25 miles below the toe of the fill, an additional station was located between the toe of the fill and the sediment pond. Two sampling stations were located within the next order receiving stream downstream. One of these stations was located above the confluence and one was located below the confluence. In general, an unmined reference station was located at a point that represented the area proposed for mining. In addition, a mined and filled reference station was located at a point that represents a similar level of mining.	Based on an agreement reached between the client and regulatory agencies. Selected to provide quantitative and qualitative characterizations of benthic macroinvertebrate communities.	The sampling station locations contained habitat which was representative of the overall habitat found within stream reach. Stations that were to be used for comparative purposes contained similar habitat characteristics. Stations bracketing a proposed fill tributary were close (approximately 100 m) to the impacted tributary. The general locations were usually pre-determined by the client and the permit writer. When descriptions of predetermined sites were vague, professional judgements were made in an attempt to incorporate the studies' goals. For selecting sampling sites for proposed VFs, site were located at the toe of the valley, below the sediment pond at the mouth of the fill stream, upstream and downstream of the fill stream on the receiving stream and on the next order receiving stream.

(Continued)

Table A-6. Continued.

Benthic Macroinvertebrate Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Sampling Point selection	The sampling point was at the middle of the reach. It was moved upstream or downstream to avoid tributary effects, bridges or fords.	No information given on specific sampling point selection.	No information given on specific sampling point selection.	One of three methods (i.e., completely randomized, stratified-random or stratified) was used to select the sampling points at a site. Generally, the stratified-random method was used in large streams and the stratified method was used in small streams. In small intermittent streams or when there was little water, samples were taken from wherever possible.
Sampler Used	Sampling was conducted according to Barbour et al. (1999). A 0.5-m rectangular kick net was used to composite four ¼-m^2 samples.	In the autumn of 1999 and the spring of 2000, four ¼-m^2 samples collected with a D-frame kick net were composited. In the autumn of 2000, six Surber samples were collected and four ¼-m^2 samples collected with a D-frame kick net were composited. In the spring of 2001, four Surber samples, were collected and four ¼-m^2 samples were collected with a D-frame kick net and composited.	Four ¼-m^2 samples were taken using a D-frame kick net and composited. Surber samplers were used at selected sampling stations.	The sampling devices were dependent on the permit. Three samples were taken using a Surber sampler. These were not composited. Four ¼-m^2 samples were taken using a D-frame kick net. These were composited. The Surber samplers were usually used in riffle areas and the kick net samples were usually taken from deeper run or pool habitats.
Surber Sampler Procedures	Surber samplers were not used.	The frame of the sampler was placed on the stream bottom in the area that was to be sampled. All large rocks and debris that are in the 1.0-ft^2 frame were scrubbed and rinsed into the net and removed from the sampling area. Then, the substrate in the frame was vigorously disturbed for 20 seconds. Each sample was rinsed and placed into a labeled container with two additional labels inside the sample containers.	The Surber sampler was placed with all sides flat on the stream bed. Large cobble and gravel within the frame were brushed. The area within the frame was disturbed to a depth of three in with the handle of the brush. The sample was transferred to a labeled plastic bottle.	The sampler was placed with the cod end downstream. The substrate upstream of the sampler was scrubbed gently with a nylon brush for up to three minutes. Water was kept flowing into sampler while scrubbing. Rocks were checked and any clinging macroinvertebrates were removed and placed in the sampler. The material in the sampler was rinsed and collected into a bottle.

(Continued)

Table A-6. Continued.

Benthic Macroinvertebrate Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Kick Net Procedures	The procedures in Barbour et al. (1999) were modified so that 1 m^2 of substrate was sampled at each site.	The net was held downstream of the 0.25-m^2 area that was to be sampled. All rocks and debris that were in the 0.25-m^2 area were scrubbed and rinsed into the net and removed from the sampling area. Then, the substrate in the 0.25-m^2 area was vigorously disturbed for 20 seconds. This process was repeated four times at each sampling site. The composited sample was rinsed and placed into a labeled container.	The kick net samples were collected using protocols in Barbour et el. (1999). All boulders, cobble and large gravel within 0.25 m^2 upstream of net were brushed into the net. The substrate within 0.25 m^2 upstream of the net was kicked for 20 seconds. Four samples were collected and composited. The sample was transferred to a labeled plastic bottle.	The sampler was placed with the net outstretched and the cod end downstream. The substrate was kicked or scrubbed for up to three minutes. Discharged material was swept into the net. An area of approximately 0.25m^2 was sampled. The procedure was repeated four times.
Additional information collected from sites	The physical/chemical field sheets were completed before sampling and they were reviewed for accuracy after sampling. A map of the sampling reach was drawn. A GPS unit was used to record latitude and longitude. After sampling, the Macroinvertebrate Field Sheet was completed. The percentage of each habitat type in the reach was recorded and the sampling gear used was noted. Comments were made on conditions of the sampling.. Observations of aquatic flora and fauna were documented. Qualitative estimates of macroinvertebrate composition and relative abundance were made. A habitat assessment was made. Riparian habitat was described using Kaufmann and Robison (1998).	Additional information collected was not described.	A field data sheet (from Barbour et al. 1999) was completed and photographic documentation was taken at the time of sampling. Photographs showed an upstream view and a downstream view from the center of the sampling reach.	Additional information collected was not described.

(Continued)

Table A-6. Continued.

Benthic Macroinvertebrate Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Sample Preservation	Samples were preserved in 95% ethanol.	Samples were preserved in 70% ethanol.	Quantitative samples were preserved in 50% isopropanol. Semi-quantitative samples were preserved in either 50% isopropanol or 70% ethanol.	Samples were preserved in the field with formaldehyde (30% by wt.). Approximately 10% of the samples' volume was added.
Logging samples	All samples were dated and recorded in a sample log notebook upon receipt by laboratory personnel. All information from the sample container label was included on the sample log sheet (Barbour et al. 1999).	Samples were logged onto Chain-of-Custody forms. Logs were maintained throughout the identification process.	When samples arrived at the laboratory, they were entered in a log book and tracked through processing and identification.	Sample logging procedure was not described.
Laboratory Procedures	Samples were thoroughly rinsed in a 500 µm-mesh sieve. Large organic material was rinsed, visually inspected, and discarded. Samples that had been preserved in alcohol, were soaked in water for approximately 15 minutes. Samples stored in more than one container were combined. After washing, the sample was spread evenly across a pan marked with grids approximately 6 cm x 6 cm. A random numbers table was used to select four grids. All material from the four grids (⅛ of the total sample) was removed and placed in a shallow white pan. A predetermined, fixed number of organisms were used to determine when sub-sampling was complete.	Samples were rinsed using a #24 sieve (0.0277-in mesh) and then transferred to an enamel tray. Water was added to the tray to a level that covered the sample. All macroinvertebrates in the sample were picked from the debris using forceps and then transferred to a vial that contained 70% ethanol. One of the labels from the sample jar was placed on the organism vial. After identification and processing, the samples were then stored according to the project plan.	Benthic macroinvertebrates were processed using the single habitat protocols in Barbour et al. (1999). The entire samples were processed. Identifications were recorded on standard forms. Ten percent of the samples are re-picked and identifications are randomly reviewed.	Samples were processed individually. They were poured into a 250-µm sieve. Then rinsed with water and transferred to a four-part sub-sampler with a 500-µm screen and distributed evenly on the with water. The first ¼ of the sample was put into petri dishes and the aquatic insects were sorted from the detritus. All macroinvertebrates were placed in a labeled bottle with formalin. If too few individuals were found in the ¼, the second ¼ was picked. Then, either a portion of the picked detritus was re-checked, or a single sorter checked all petri dishes. If organisms were present, the sample was re-picked. After sample sorting was complete, picked and unpicked detritus was stored.

(Continued)

Table A-6. Continued.

Benthic Macroinvertebrate Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Benthic Macro-invertebrate Identification	Organisms were identified to the lowest practical taxon by a qualified taxonomist. Each taxon found in a sample was recorded and enumerated in a bench notebook and then transcribed to the laboratory bench sheet for subsequent reports. Any difficulties encountered during identification were noted on these sheets. Labels with specific taxa names were added to the vials of specimens. The identity and number of organisms were recorded on the bench sheet. Life stages of organisms were also recorded (Barbour et al. 1999).	Using a binocular compound microscope, each organism was identified to the taxa level specified in the project study plan. The numbers of organisms found in each taxa were recorded on bench sheets. Then, the organisms and sample label were returned to the organism vial and preserved with 70% ethanol. For QC purposes, 10% of all samples were re-identified.	Samples were identified by qualified freshwater macroinvertebrate taxonomists to the lowest practical taxon.	Aquatic insects were identified under a microscope to the lowest practical taxonomic level. Unless specified otherwise, Chironomids were identified to the Family level and Annelids were broken into classes. Identified specimens were returned to the sample bottle and preserved in formalin. New or extraordinary taxa were added to reference collections. Random samples are re-identified periodically.
Macro-invertebrate Sample Storage	Samples were stored for at least six months. Specimen vials were placed in jars with a small amount of 70% ethanol and tightly capped. The ethanol level in these jars was examined periodically and replenished as needed. A label was placed on the outside of the jar indicating sample identifier, date, and preservative.	No information on sample storage was provided.	No information on sample storage was provided.	Samples were stored for at least six months.
Database Construction	No information on database construction was provided.	No information on database construction was provided.	The data from the taxonomic identification sheets were transferred into spreadsheets. Data entered into the spreadsheets were routinely checked against field and laboratory sheets.	No information on database construction was provided.
Benthic Macro-invertebrate Data Analysis	Data were used to calculate the WVSCI.	No information on data analysis was provided.	Eight bioassessment metrics were calculated for each sampling station.	Twelve benthic macroinvertebrate metrics were calculated for each of the sampling stations. Abundance data from sub-sampling was extrapolated to equal the entire sample amount.

(Continued)

Table A-6. Continued.

Benthic Macroinvertebrate Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Benthic Macro-invertebrate Metrics Calculated	Data were used to calculate the metrics of the WVSCI.	No information on metrics was provided.	1. Taxa Richness 2. Total Number of Individuals 3. Percent Mayflies 4. Percent Stoneflies 5. Percent caddisflies 6. Total Number of EPT Taxa 7. Percent EPT Taxa 8. Percent Chironomidae	1. Taxa Richness 2. Modified HBI: Summarizes overall pollution tolerance. 3. Ratio of Scrapers to Filtering Collectors 4. Ratio of EPTs to Chironomidae 5. Percent of Mayflies 6. Percent of Dominant Family 7. EPT Index: Total number of distinct taxa within EPT Orders. 8. Ratio of Shredders to Total Number of Individuals 9. Simpson's Diversity Index 10. Shannon-Wiener Diversity Index 11. Shannon-Wiener Evenness 12. West Virginia Stream Condition Index: a six-metric index of ecosystem health.

APPENDIX B

IBI COMPONENT METRIC VALUES

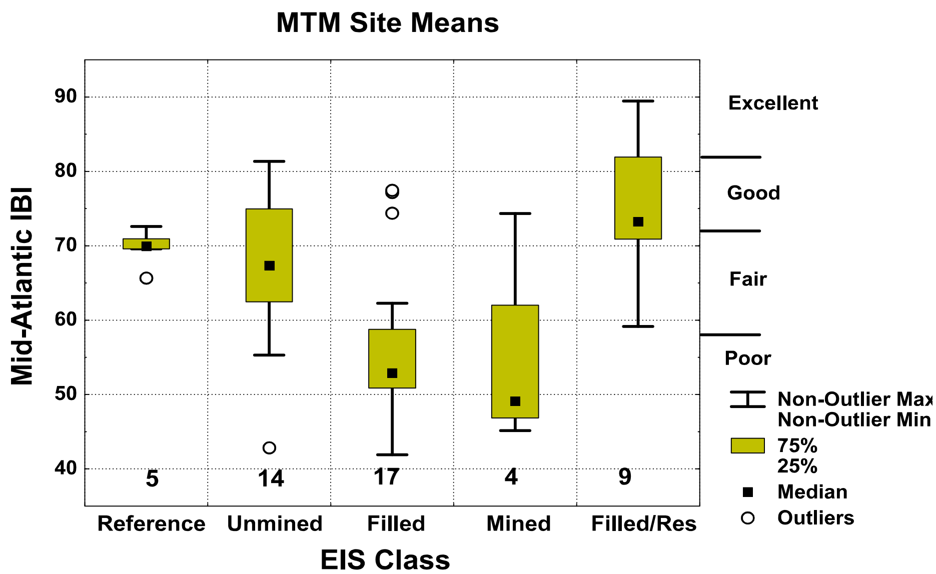

Figure B-1. Box plot of the IBI among EIS classes and regional reference sites. All taxa richness metrics were adjusted to a catchment area of 100 km2.

Table B-1. The ANOVA for IBI scores among EIS classes (Unmined, Filled, Mined, and Filled/Residential).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2335.56	778.52	6.70	0.0009
Error	40	4651.31	116.28		
Corrected Total	43	6986.87			

R-Square	Coefficient of Variance	Root MSE	Index Mean
0.334	17.022	10.783	63.350

Table B-2. Dunnett's test comparing IBI values of EIS classes to the Unmined class, with the alternative hypothesis that IBI < Unmined IBI (one-tailed test).

EIS Class	N	Mean	Standard Deviation	Dunnett's P-Value
Filled	17	56.8	10.6	0.0212
Filled/Residential	9	74.6	10.7	0.9975
Mined	4	54.4	13.4	0.0685
Unmined	14	66.7	10.3	--

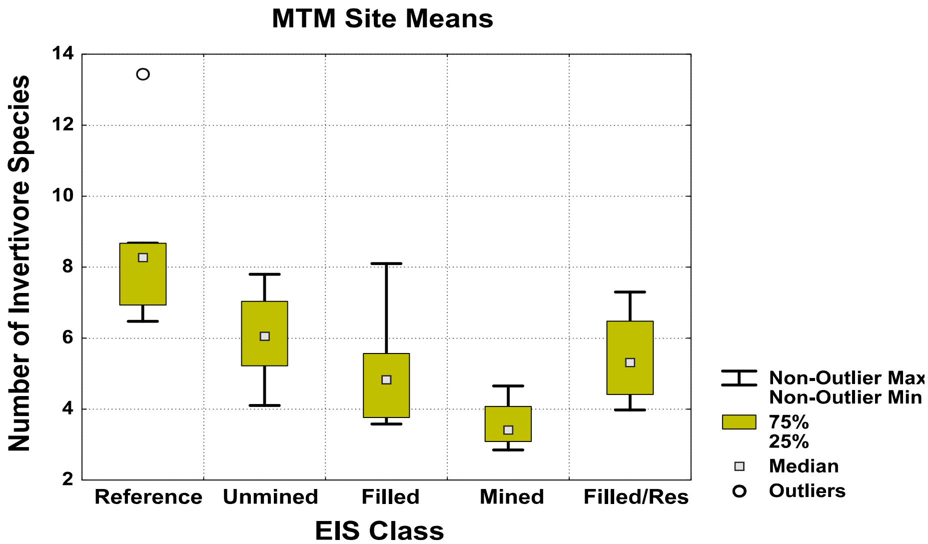

Figure B-2. Box plot of the Number of Benthic Invertivore Species among EIS classes and regional reference sites.

Table B-3. The ANOVA for Number of Benthic Invertivore Species among EIS classes (Unmined, Filled, Mined, and Filled/Residential).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	22.32	7.44	4.91	0.0054
Error	40	60.66	1.51		
Corrected Total	43	82.98			

R-Square	Coefficient of Variance	Root MSE	Index Mean
0.269	23.504	1.231	5.239

Table B-4. Dunnett's test comparing Numbers of Benthic Invertevores to the Unmined class, with the alternative hypothesis that IBI < Unmined IBI (one-tailed test).

EIS Class	N	Mean	Standard Deviation	Dunnett's P-Value
Filled	17	4.8	1.3	0.0182
Filled/Residential	9	5.4	1.2	0.3234
Mined	4	3.6	0.76	0.0017
Unmined	14	6.0	1.2	--

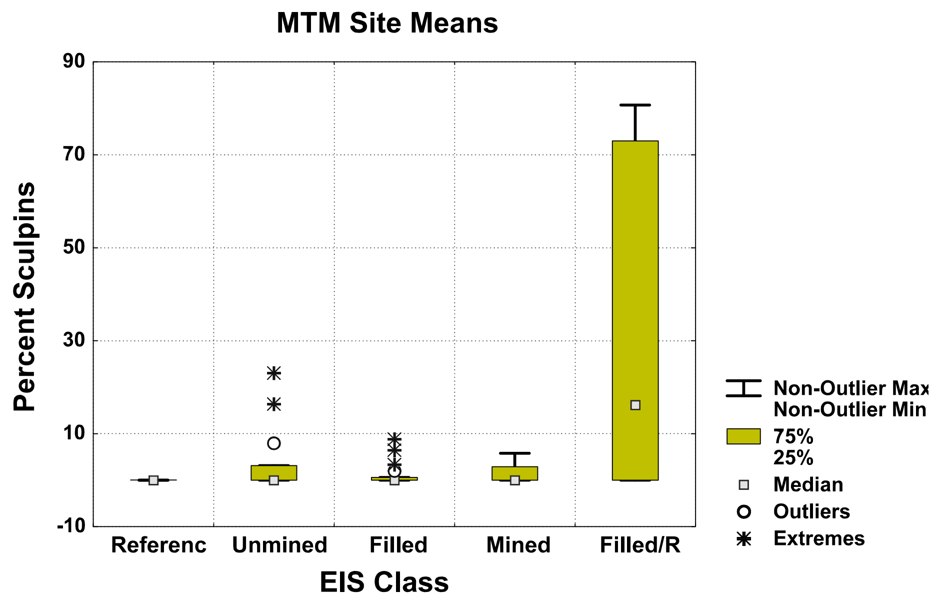

Figure B-3. Box plot of the Percent Cottidae(Sculpins) among EIS classes and regional reference sites.

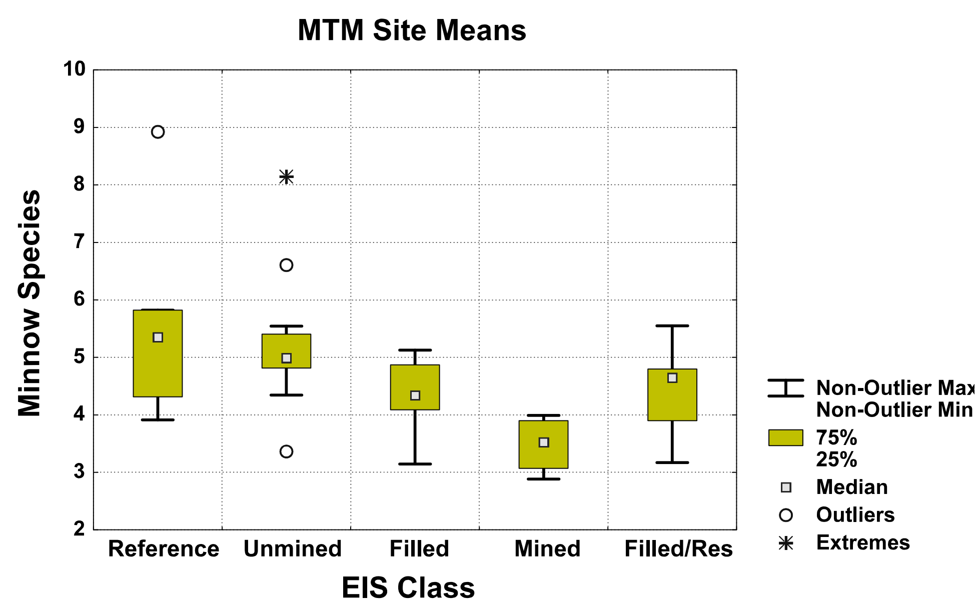

Figure B-4. Box plot of the Number of Native Cyprinidae (Minnow Species) among EIS classes and regional reference sites. This metric was adjusted to a catchment area of 100 km2.

Table B-5. The ANOVA for Number of Native Cyprinidae (Minnow Species) among EIS classes (Unmined, Filled, Mined, and Filled/Residential).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	11.36	3.79	5.79	0.0022
Error	40	26.19	0.65		
Corrected Total	43	37.56			

R-Square	Coefficient of Variance	Root MSE	Index Mean
0.302	17.777	0.809	4.55

Table B-6. Dunnett's test comparing Numbers of Native Cyprinidae (Minnows Species) to the Unmined class, with the alternative hypothesis that IBI < Unmined IBI (one-tailed test).

EIS Class	N	Mean	Standard Deviation	Dunnett's P-Value
Filled	17	4.3	0.58	0.0089
Filled/Residential	9	4.4	0.73	0.0311
Mined	4	3.5	0.51	0.0008
Unmined	14	5.2	1.1	--

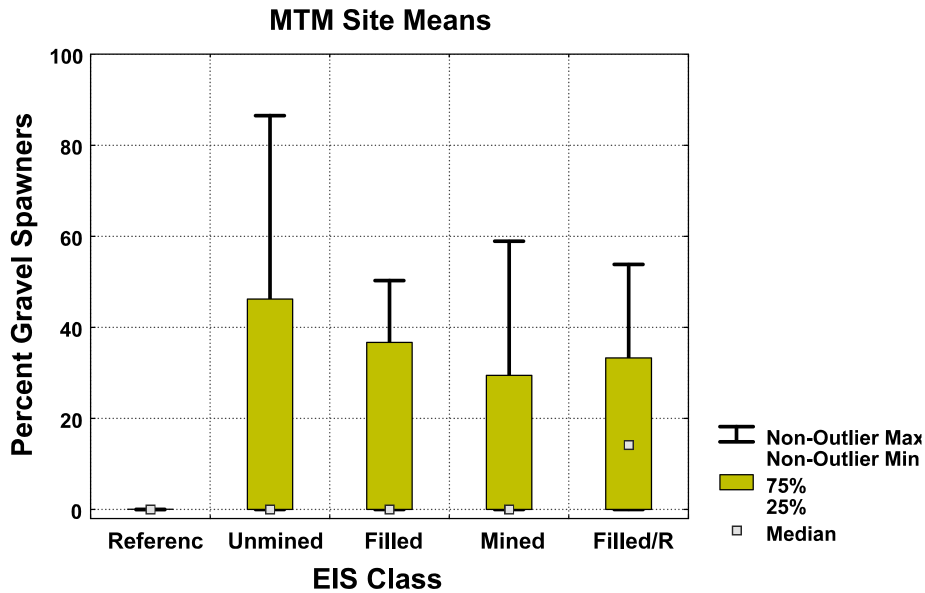

Figure B-5. Box plot of the Percent Gravel Spawners among EIS classes and regional reference sites.

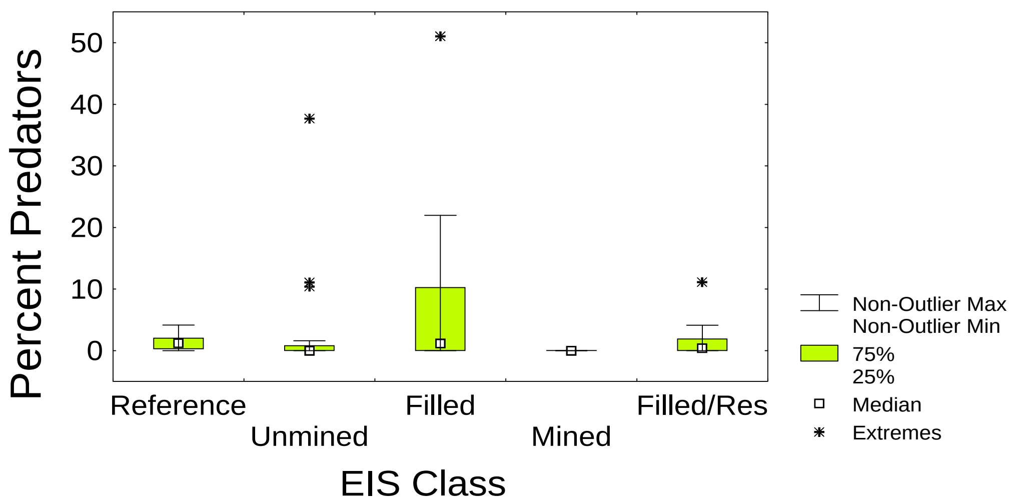

Figure B-6. Box plot of the Percent Piscivore/Invertivores (Predators) among EIS classes and regional reference sites.

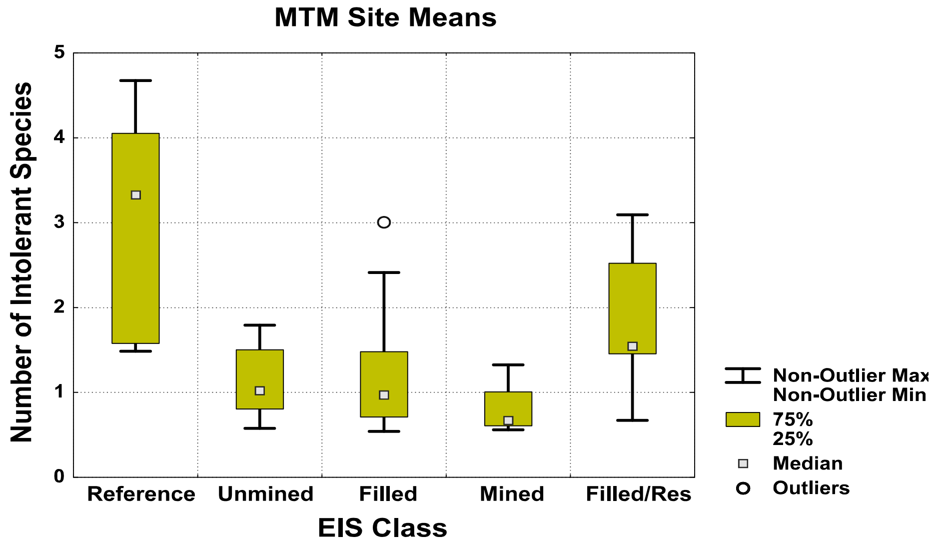

Figure B-7. Box plot of the Number of Intolerant Species among EIS classes and regional reference sites. This metric was adjusted to a catchment area of 100 km2.

Table B-7. The ANOVA for Number of Intolerant Species among EIS classes (Unmined, Filled, Mined, and Filled/Residential).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	5.29	1.76	5.96	0.0019
Error	40	11.83	0.29		
Corrected total	43	17.12			

R-Square	Coefficient of Variance	Root MSE	Index Mean
0.308	44.209	0.543	1.23

Table B-8. Dunnett's test comparing Numbers of Intolerants to the Unmined class, with the alternative hypothesis that IBI < Unmined IBI (one-tailed test).

EIS Class	N	Mean	Standard Deviation	Dunnett's P-Value
Filled	17	1.1	0.49	0.7075
Filled/Residential	9	1.9	0..83	1.0000
Mined	4	0.8	0.35	0.3504
Unmined	14	1.1	0.40	--

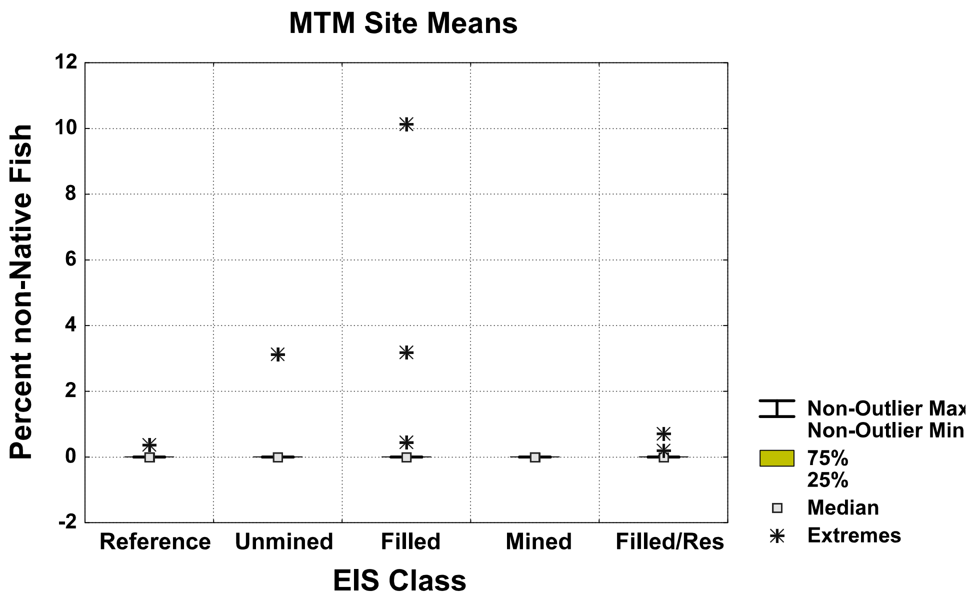

Figure B-8. Box plot of the Percent Exotic (Non-Native Fish) among EIS classes and regional reference sites.

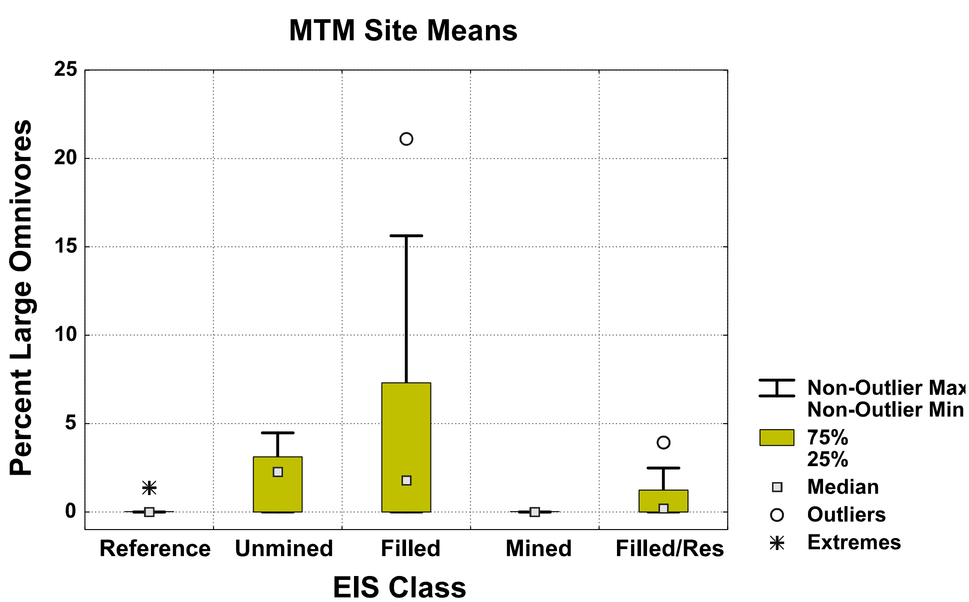

Figure B-9. Box plot of the Percent Macro Omnivores among EIS classes and regional reference sites.

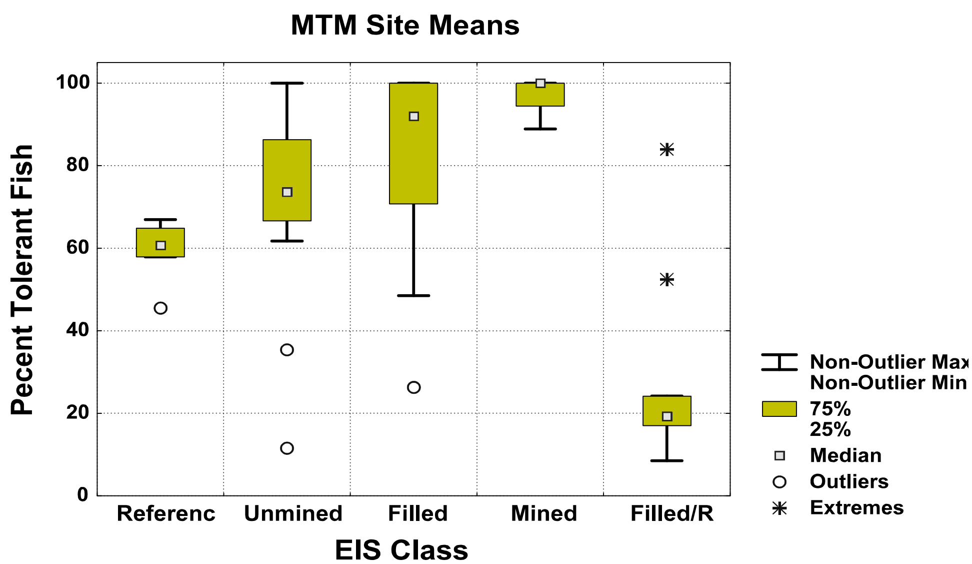

Figure B-10. Box plot of the Percent Tolerant Fish among EIS classes and regional reference sites.

Table B-9. The ANOVA for Number of Tolerant Species among EIS classes (Unmined, Filled, Mined, and Filled/Residential).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	21001.35	7000.45	14.03	<0.0001
Error	40	19956.38	498.91		
Corrected total	43	40957.73			

R-Square	Coefficient of Variance	Root MSE	Index Mean
0.512	32.055	22.336	69.681

Table B-10. Dunnett's test comparing Numbers of Tolerant Species to the Unmined class, with the alternative hypothesis that IBI < Unmined IBI (one-tailed test).

EIS Class	N	Mean	Standard Deviation	Dunnett's P-Value
Filled	17	82.9	21.5	0.2080
Filled/Residential	9	28.9	24.1	1.0000
Mined	4	97.2	5.6	0.0681
Unmined	14	71.8	24.6	--

APPENDIX C

BOX PLOTS OF THE WVSCI AND COMPONENT METRICS

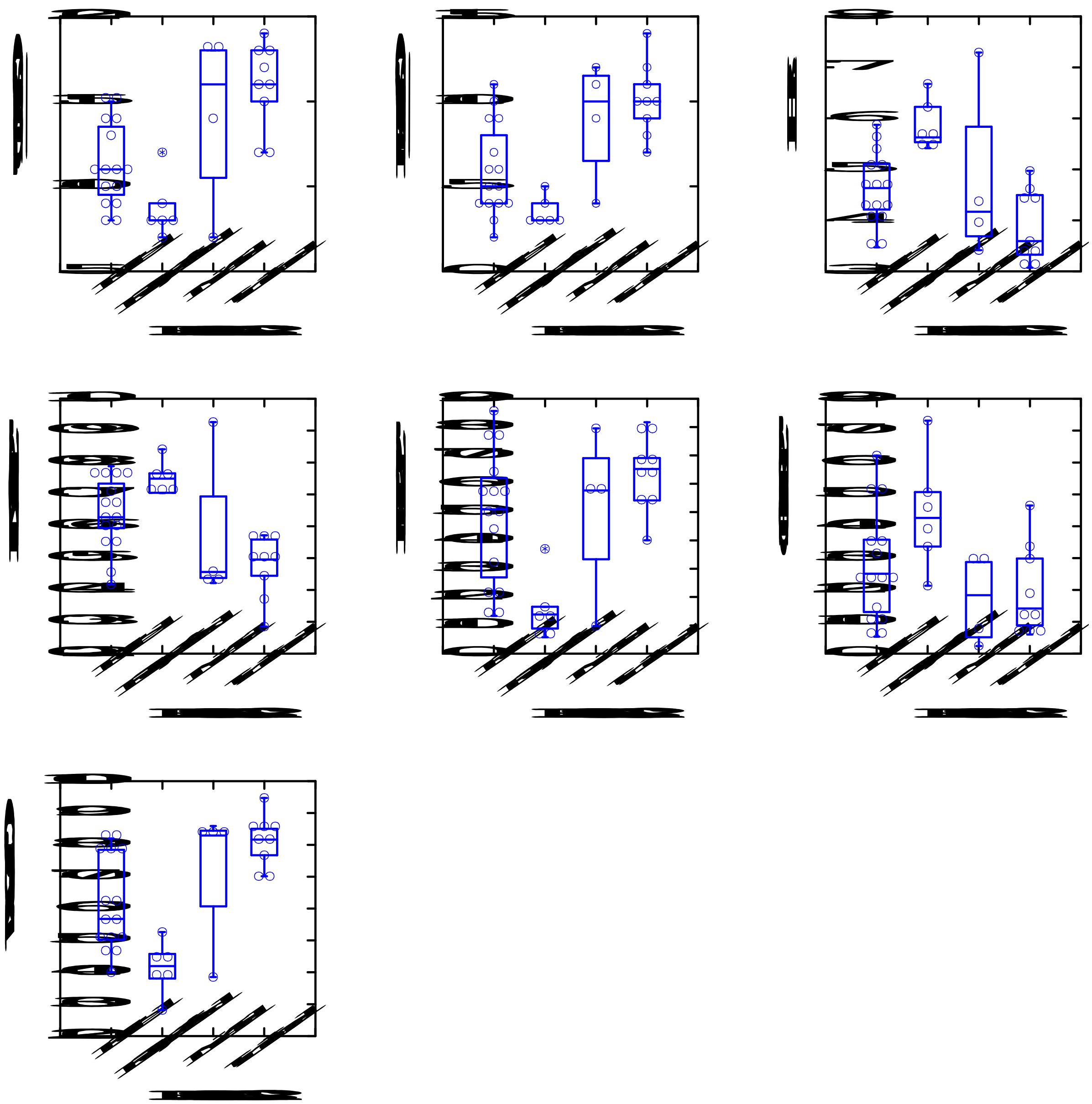

Figure C-1. Box plots of the WVSCI and its component metrics versus the EIS class for the spring 1999 season. Circles represent site scores.

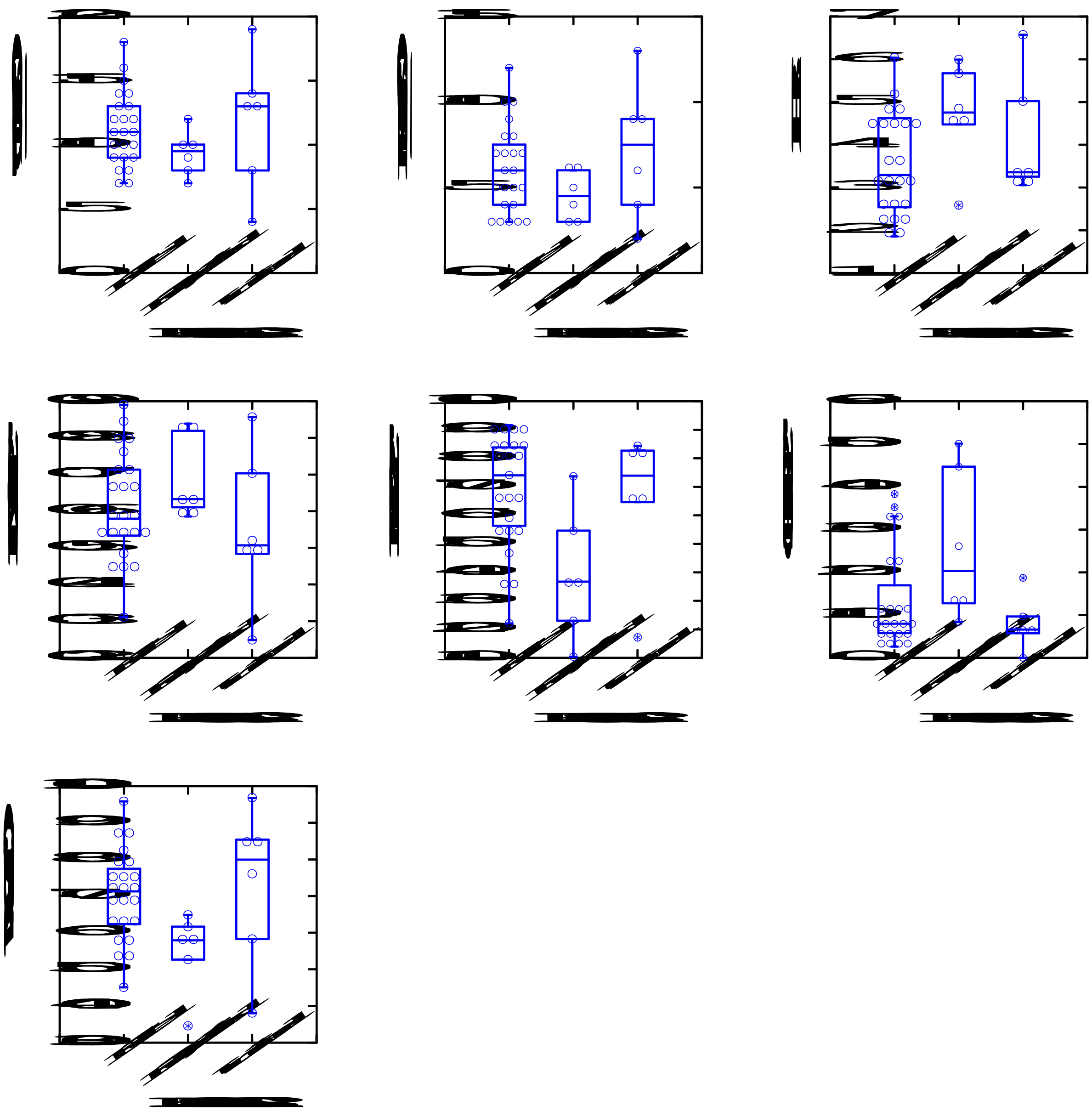

Figure C-2. Box plots of the WVSCI and its component metrics versus the EIS class for the autumn 1999 season. Circles represent site scores.

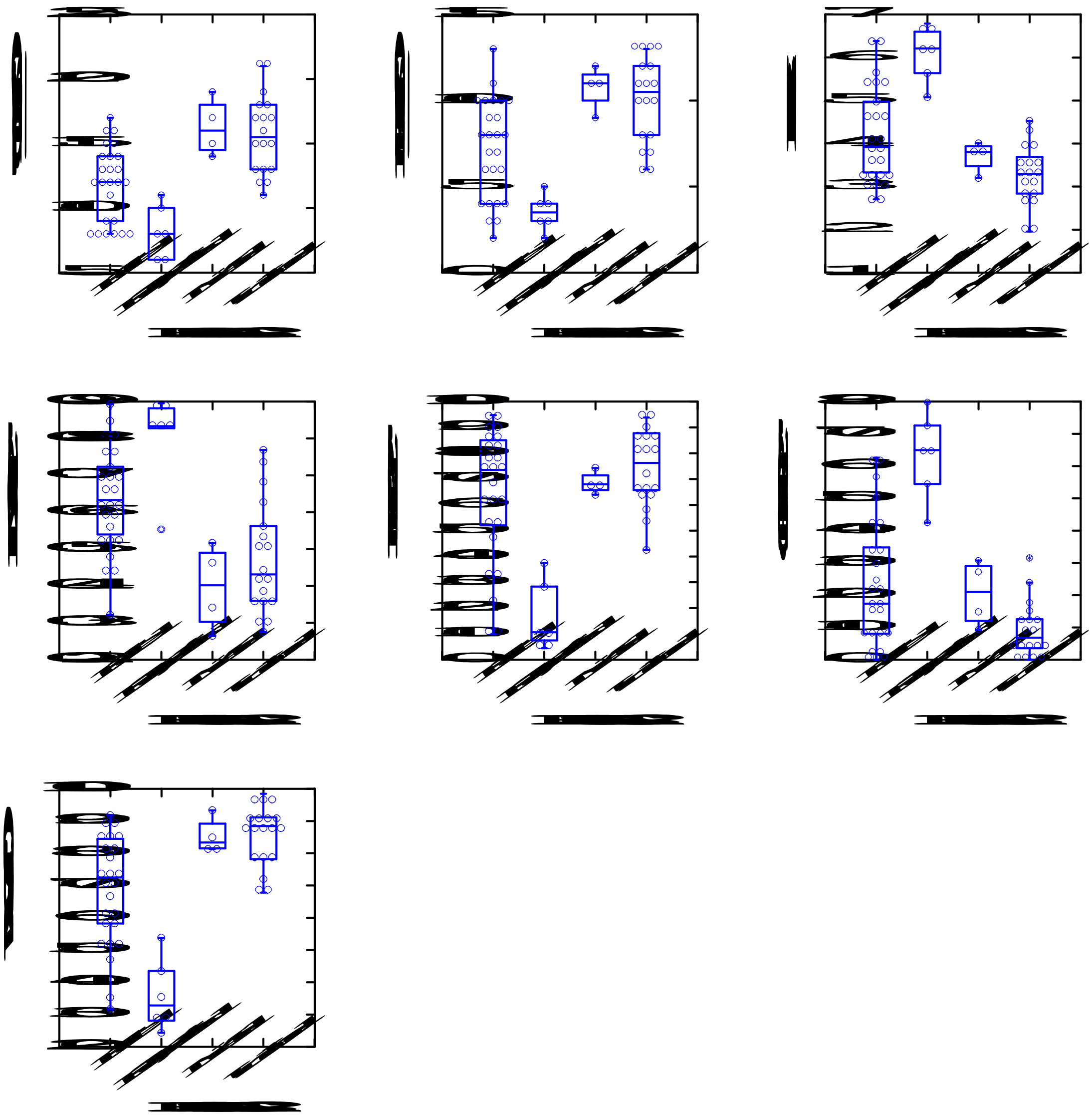

Figure C-3. Box plots of the WVSCI and its component metrics versus the EIS class for the winter 2000 season. Circles represent site scores.

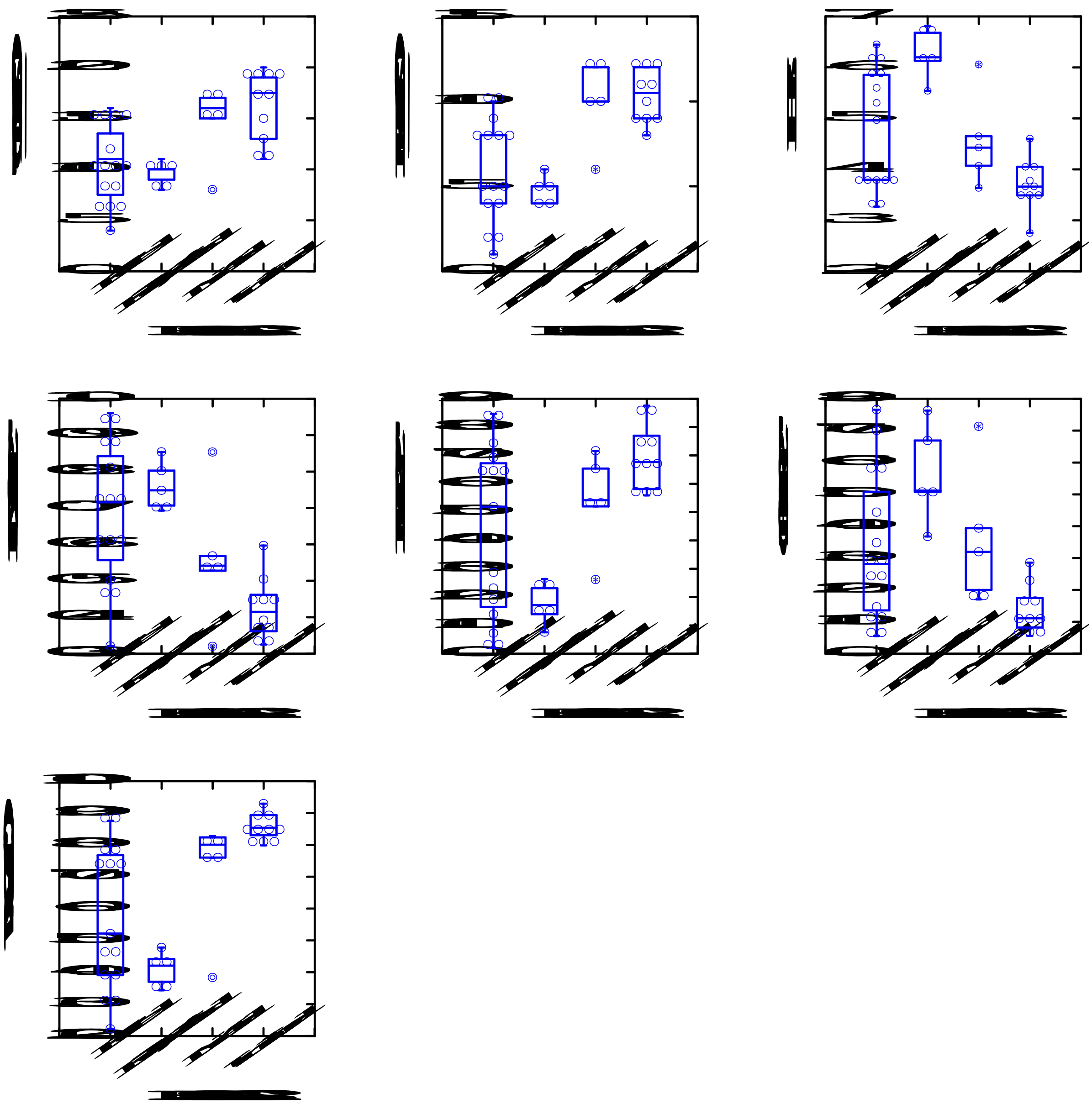

Figure C-4. Box plots of the WVSCI and its component metrics versus the EIS class for the spring 2000 season. Circles represent site scores.

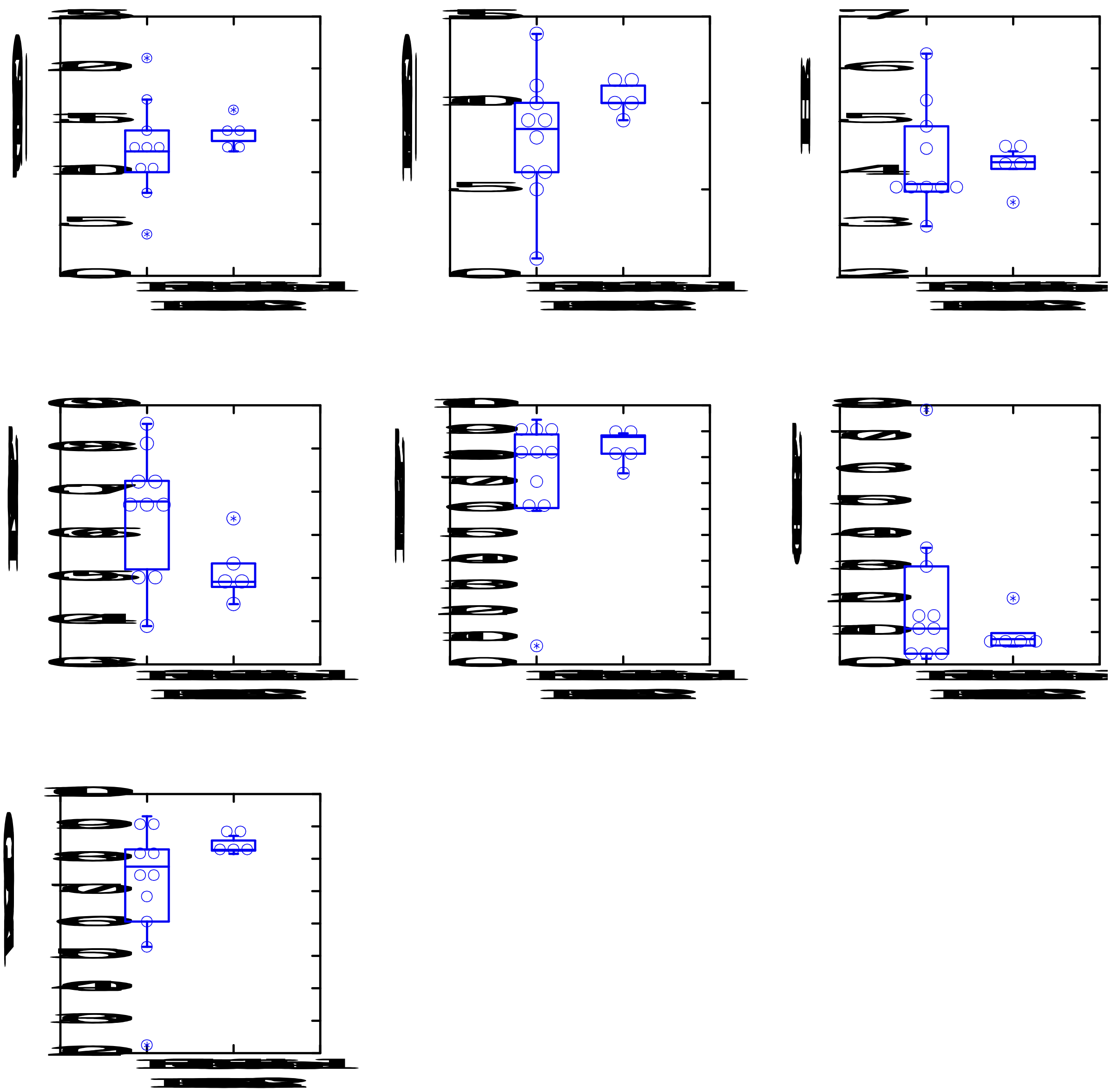

Figure C-5. Box plots of the WVSCI and its component metrics versus the EIS class for the autumn 2000 season. Circles represent site scores.

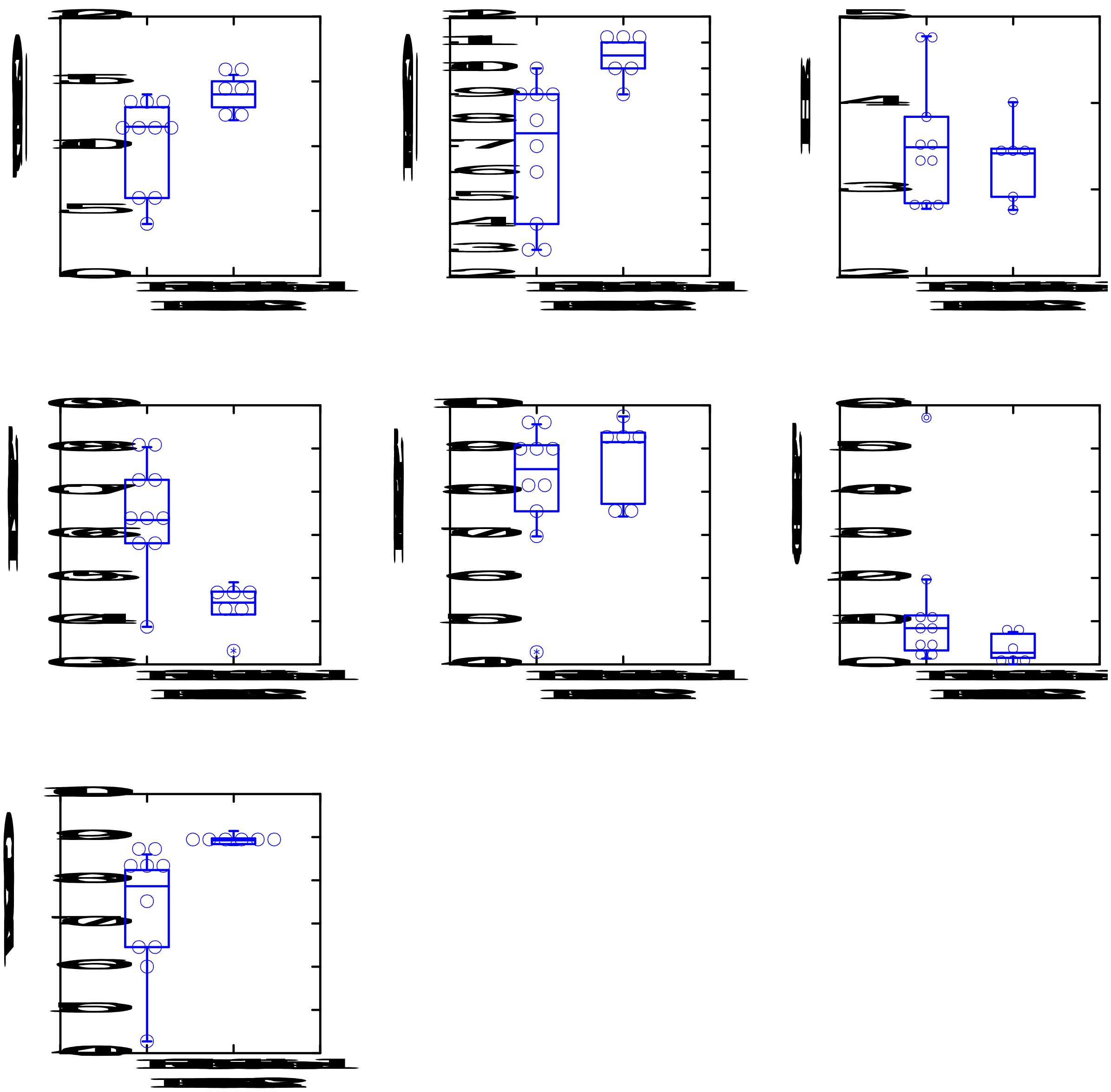

Figure C-6. Box plots of the WVSCI and its component metrics versus the EIS class for the winter 2001 season. Circles represent site scores.

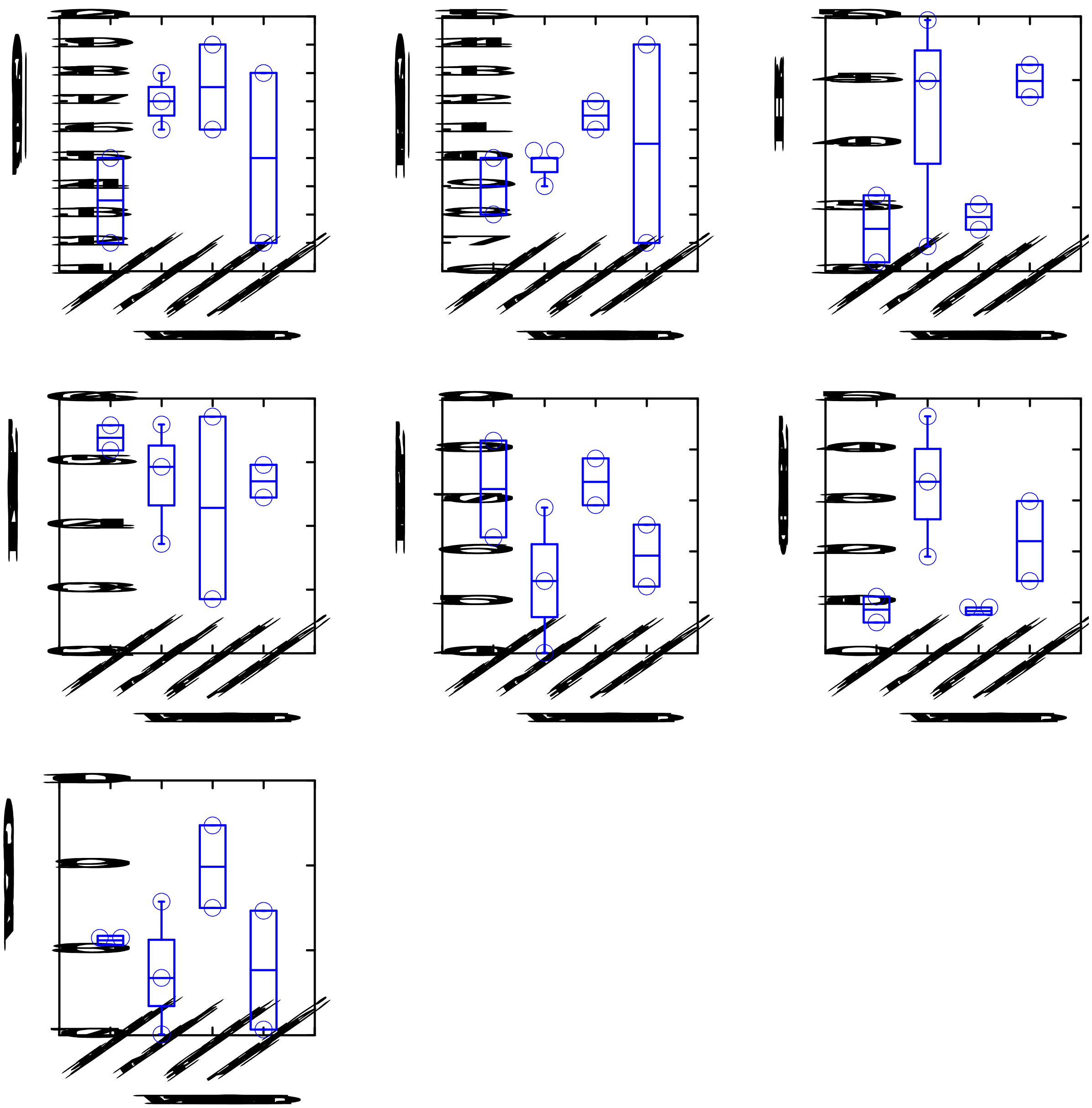

Figure C-7. Box plots of the WVSCI and its component metrics versus watershed for unmined sites in the spring 1999 season.

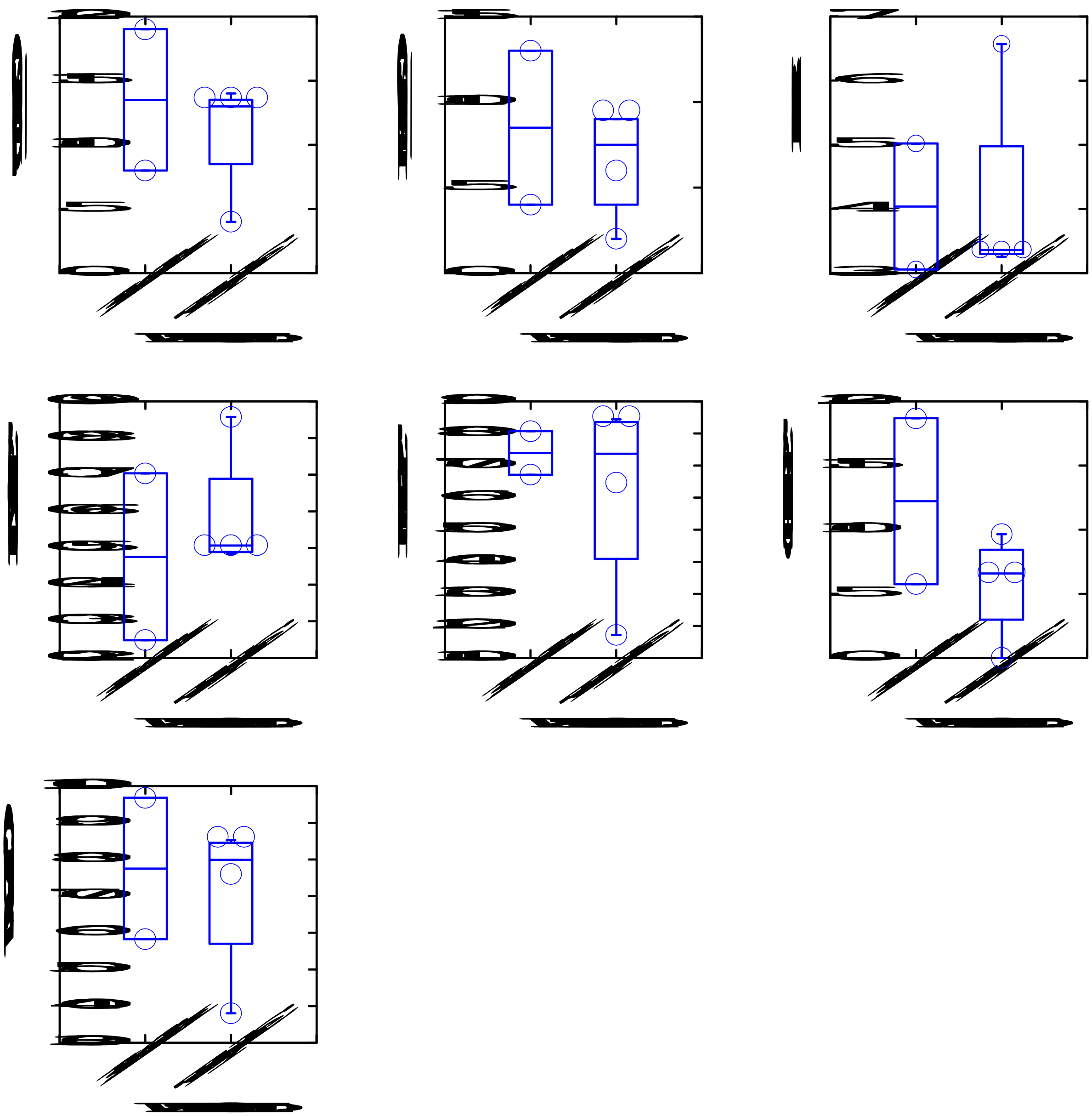

Figure C-8. Box plots of the WVSCI and its component metrics versus watershed for unmined sites in the autumn 1999 season.

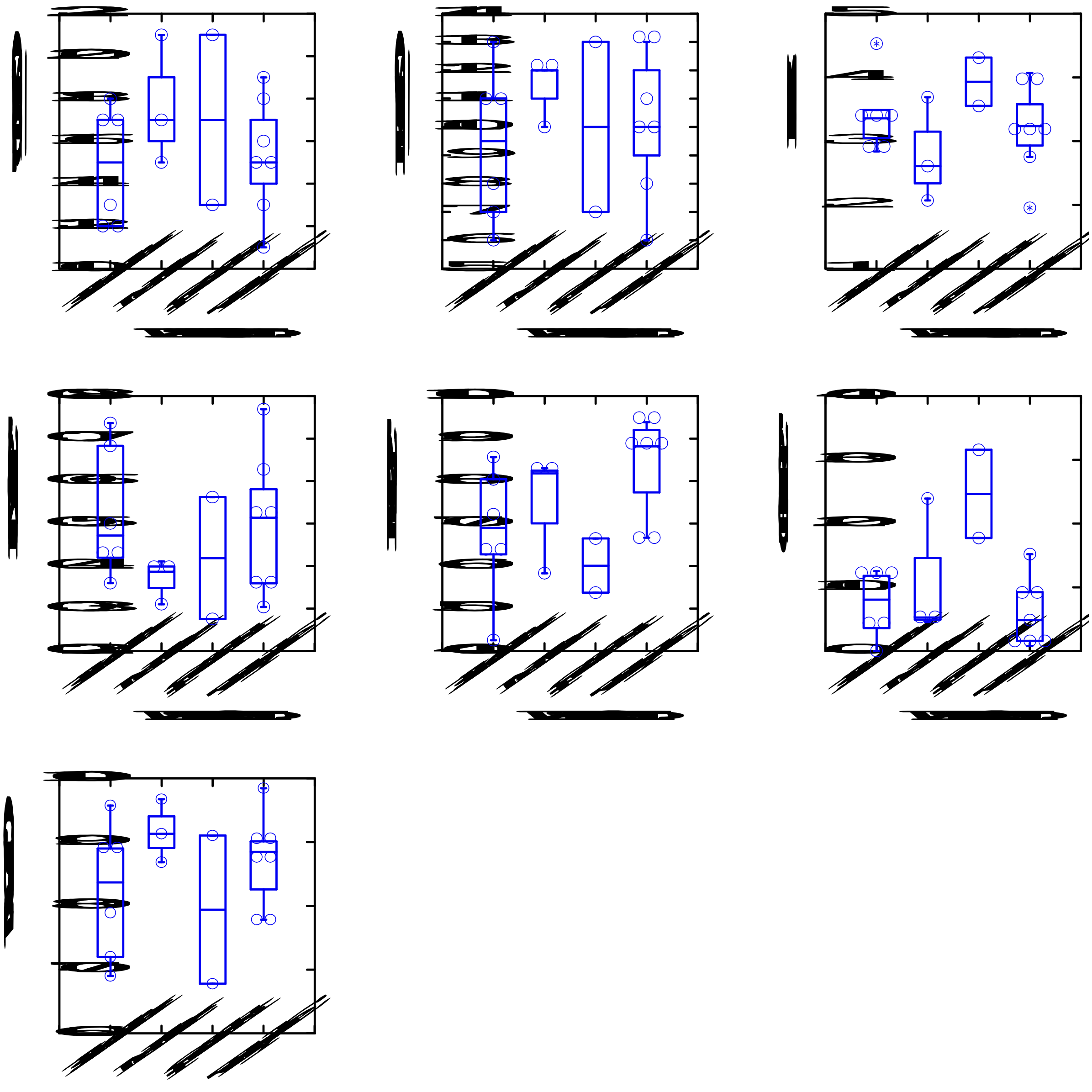

Figure C-9. Box plots of the WVSCI and its component metrics versus watershed for unmined sites in the winter 2000 season.

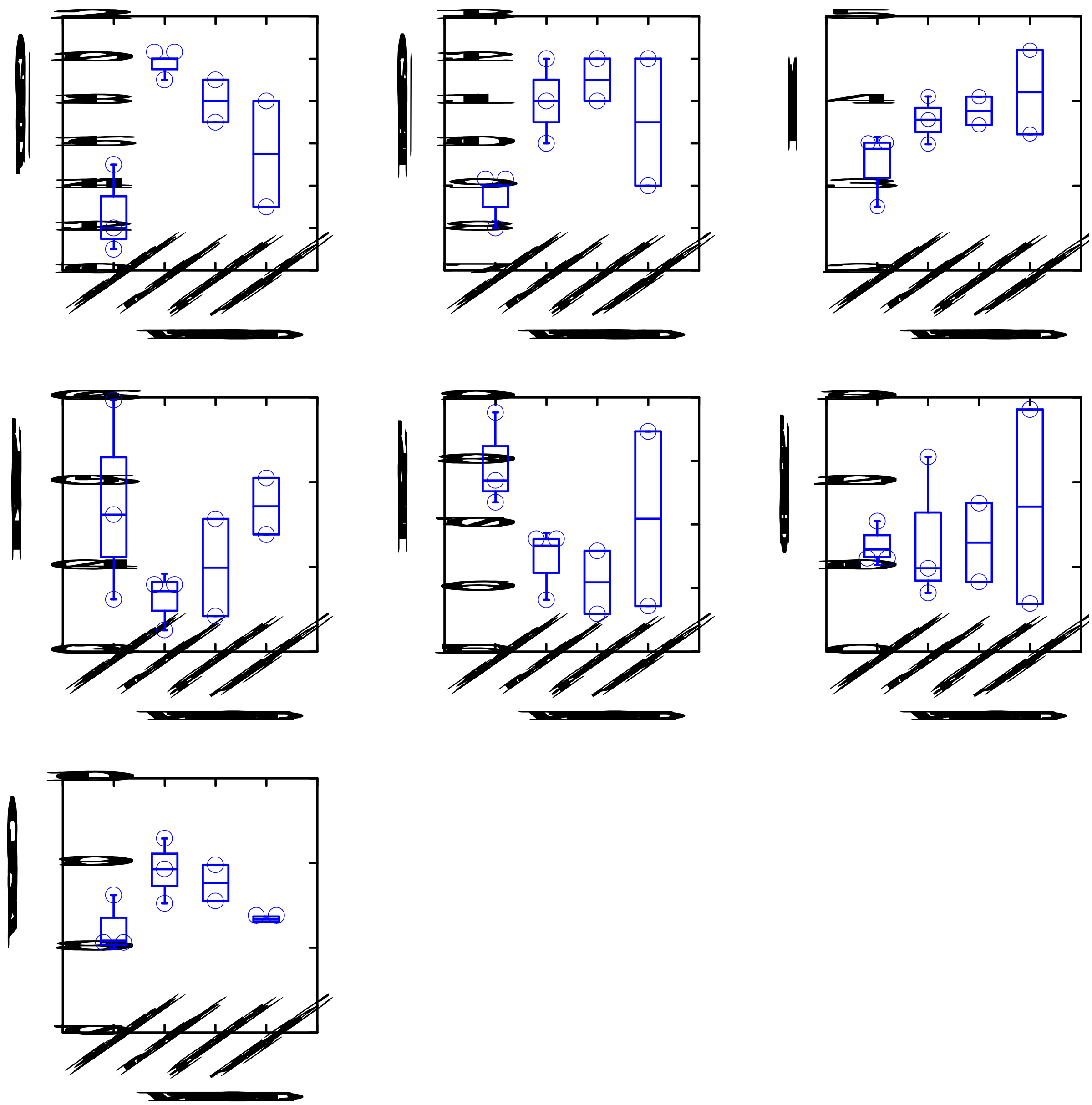

Figure C-10. Box plots of the WVSCI and its component metrics versus watershed for unmined sites in the spring 2000 season.

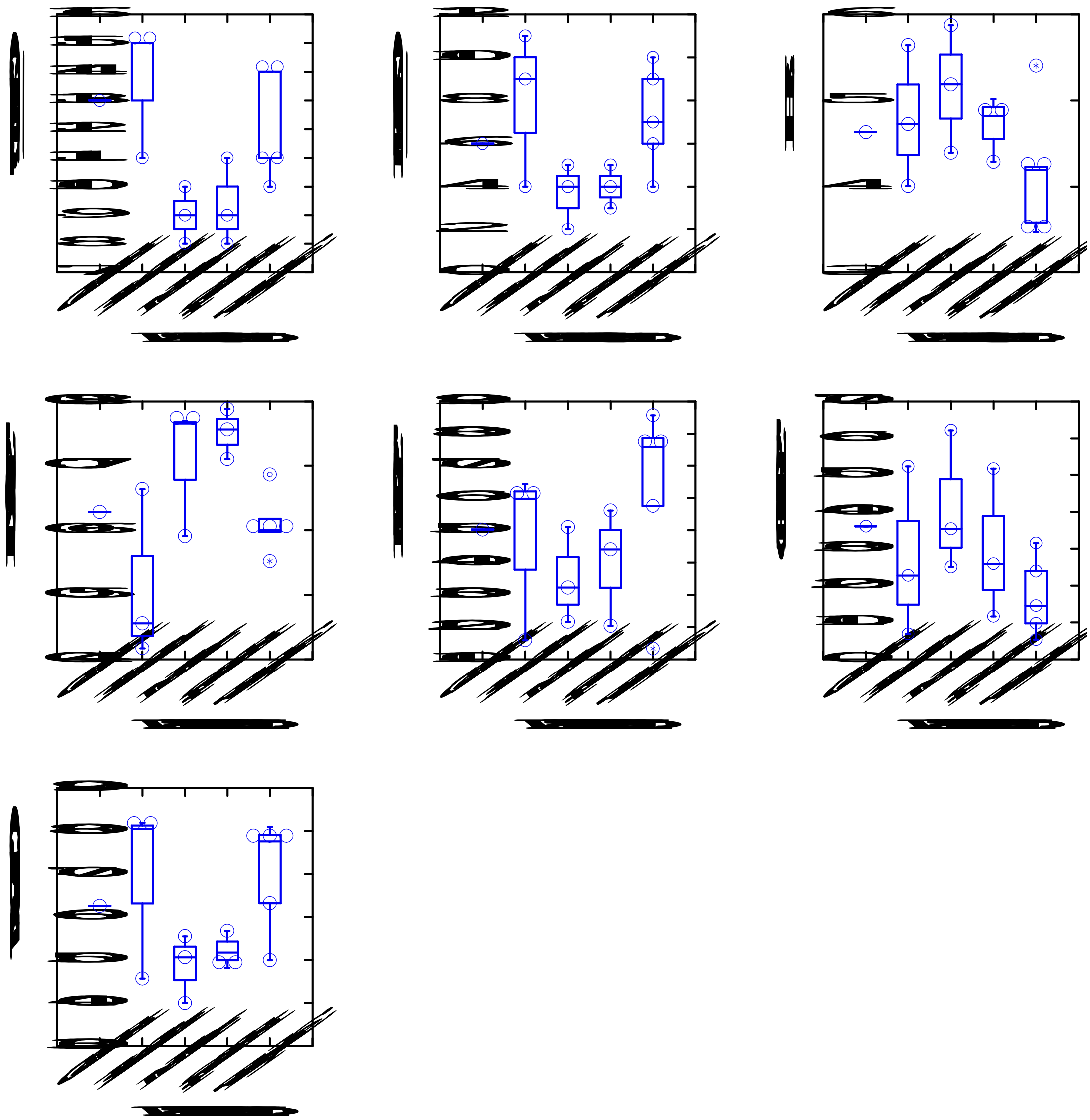

Figure C-11. Box plots of the WVSCI and its component metrics versus watershed for Filled sites in the spring 1999 season. Circles represent site scores.

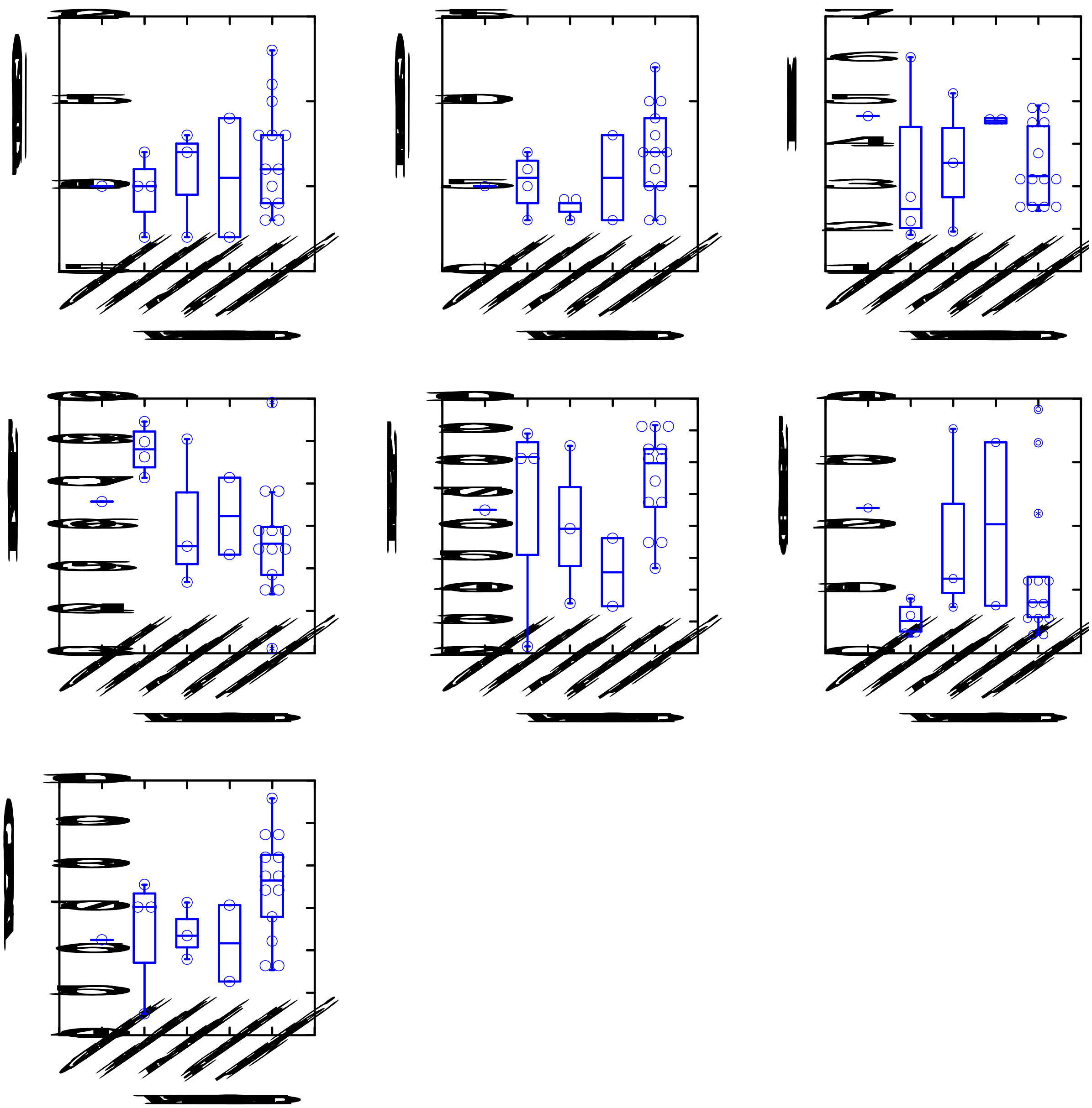

Figure C-12. Box plots of the WVSCI and its component metrics versus watershed for Filled sites in the autumn 1999 season. Circles represent site scores.

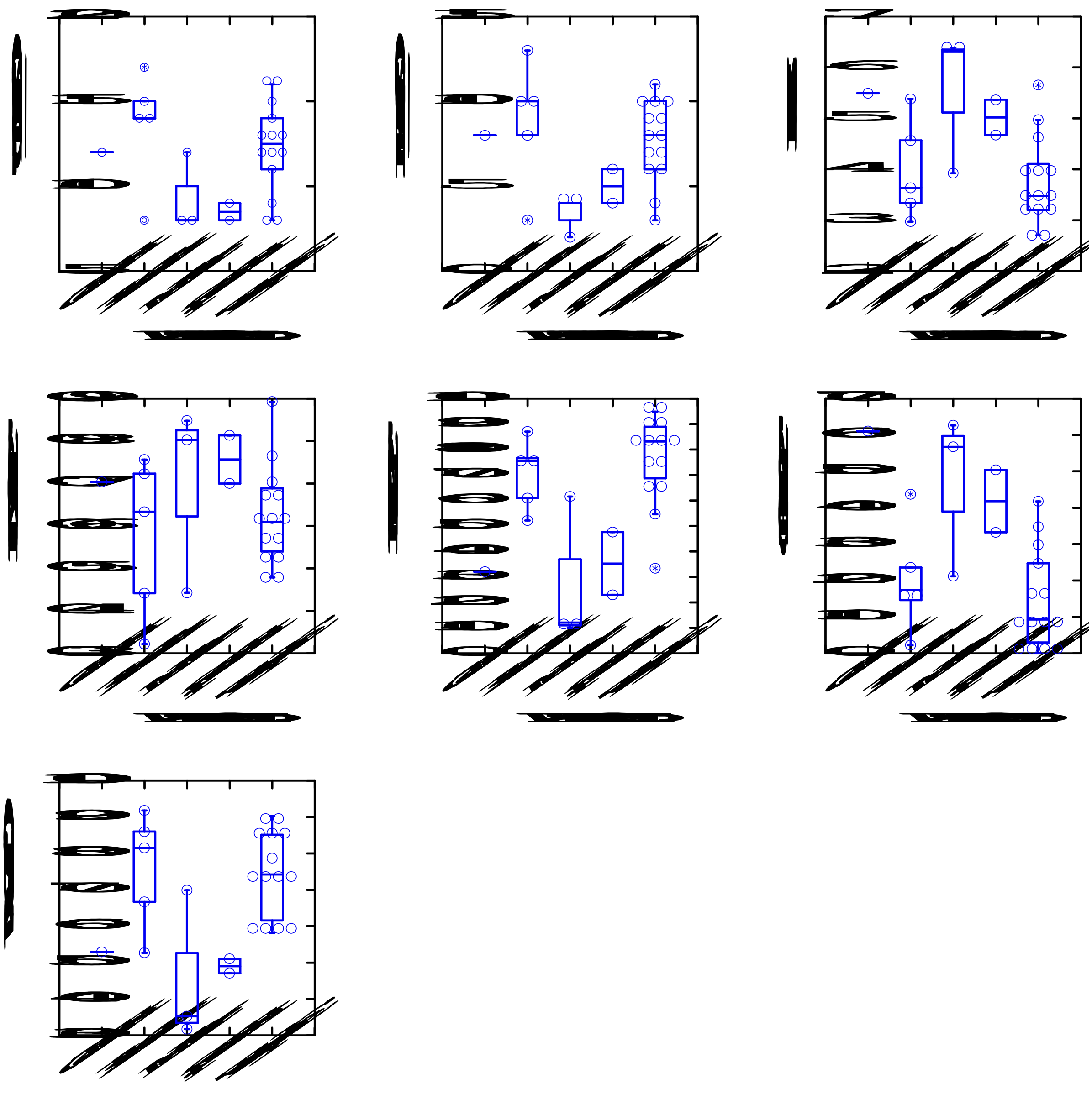

Figure C-13. Box plots of the WVSCI and its component metrics versus watershed for Filled sites in the winter 2000 season. Circles represent site scores.

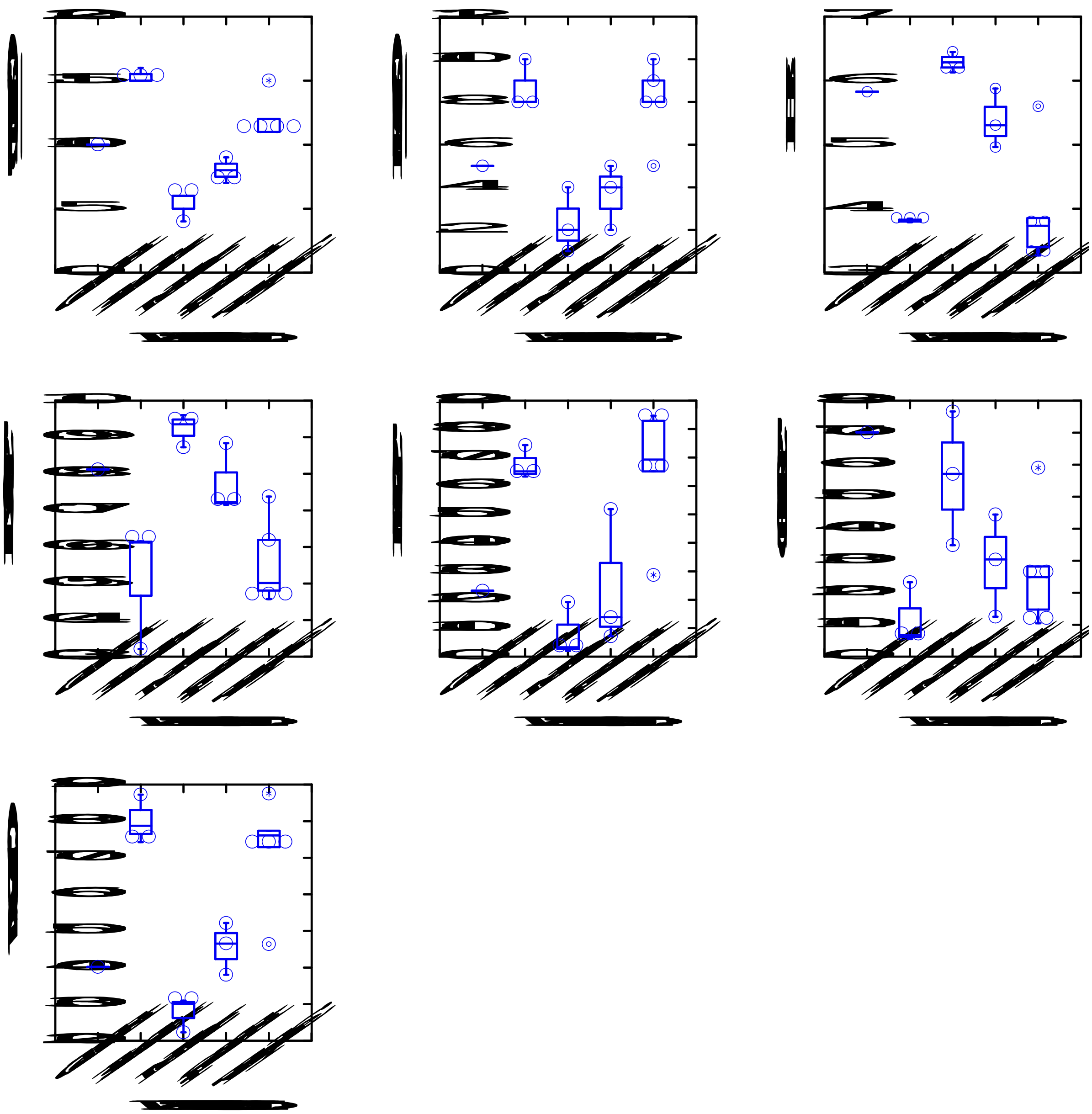

Figure C-14. Box plots of the WVSCI and its component metrics versus watershed for Filled sites in the spring 2000 season. Circles represent site scores.

APPENDIX D

SCATTER PLOTS OF THE WVSCI VERSUS KEY WATER QUALITY PARAMETERS

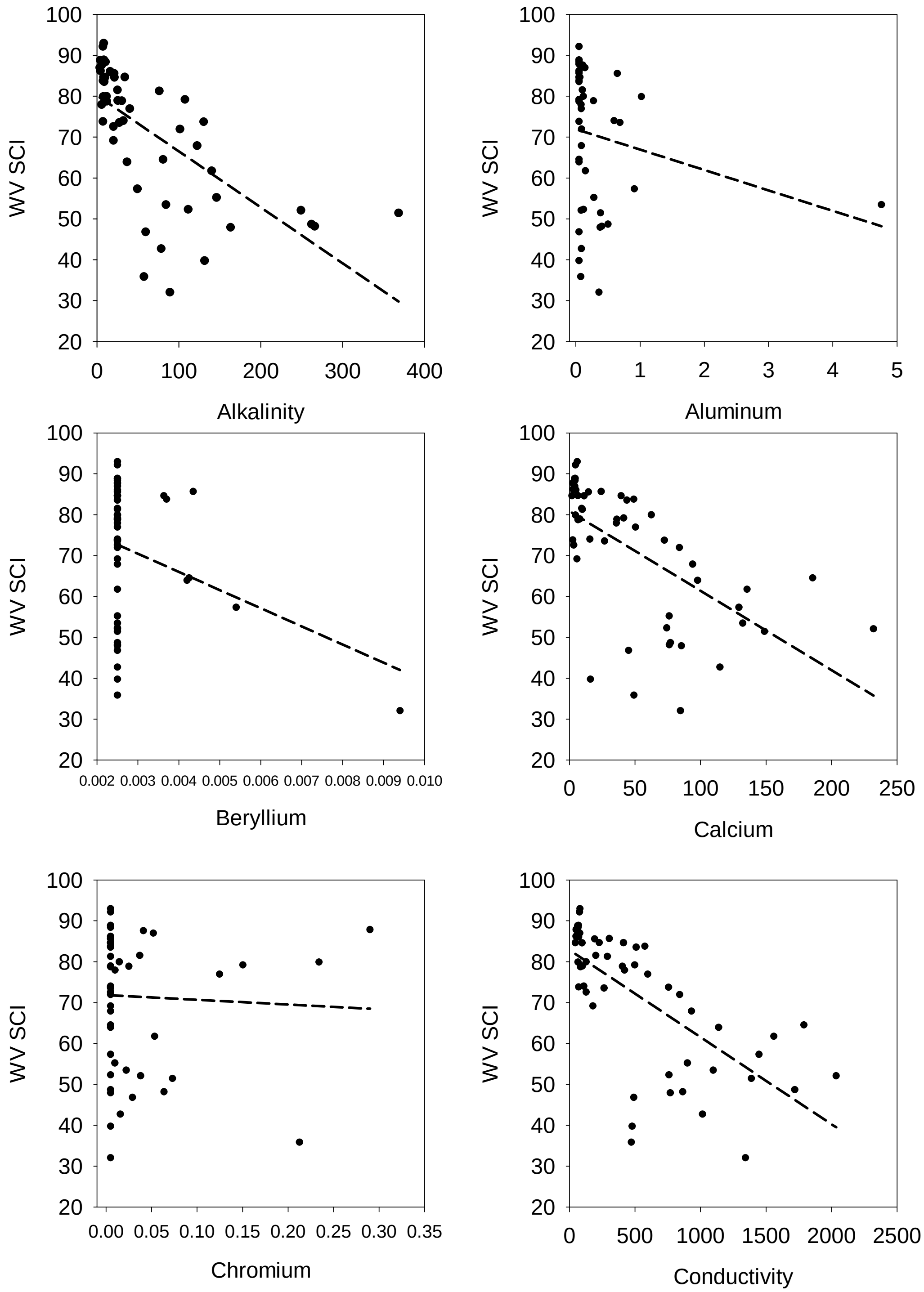
WV SCI
100
90
80
70
60
50
40
30
20
0
100
200
300
400
Alkalinity
0
1
2
3
4
5
Aluminum
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
0.010
Beryllium
0
50
100
150
200
250
Calcium
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Chromium
0
500
1000
1500
2000
2500
Conductivity

Figure D-1. The WVSCI, rarefied to 100 organisms, versus water quality parameters. Dashed line represents best fit line using linear regression.

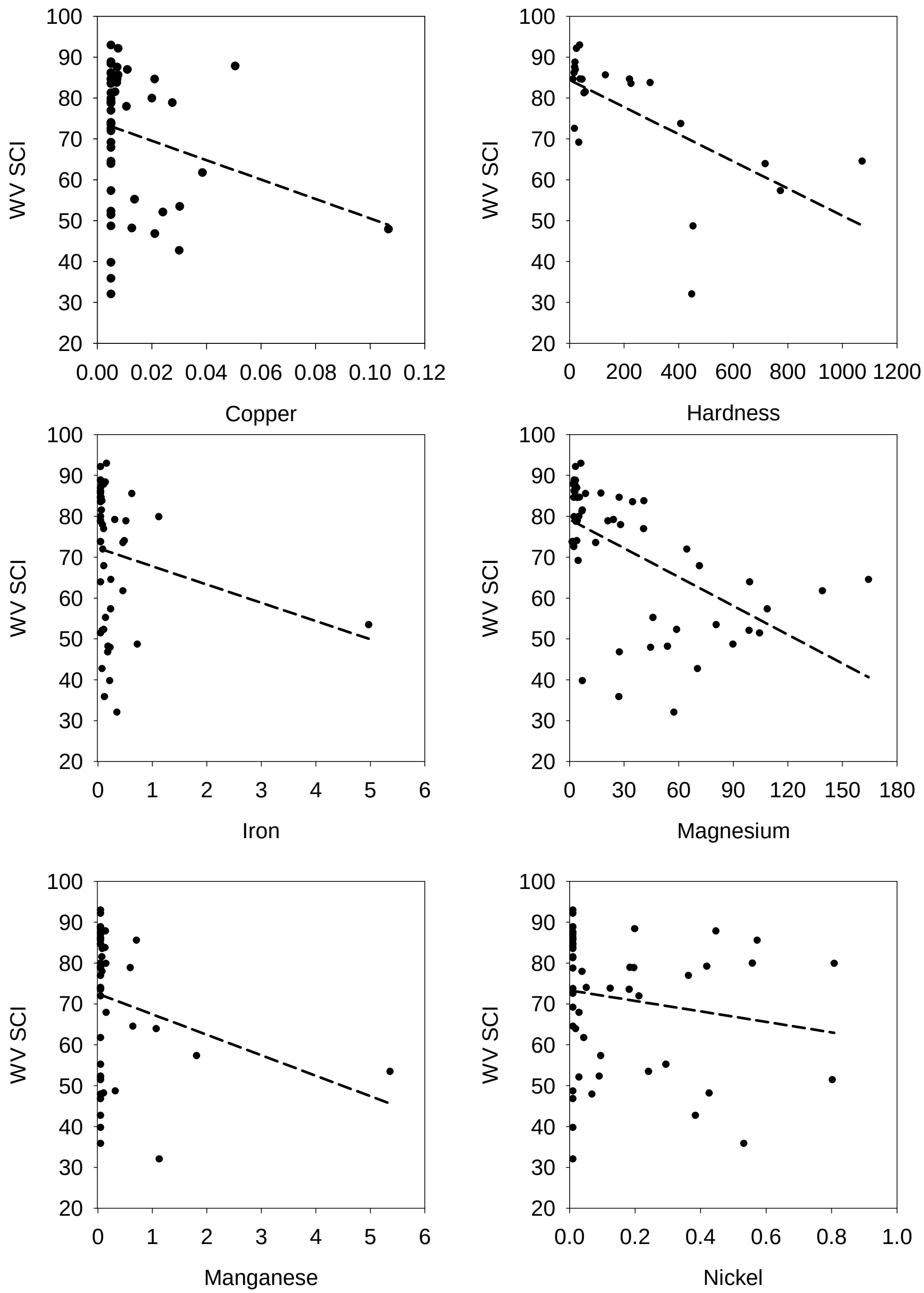
WV SCI
100
90
80
70
60
50
40
30
20
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Copper
0
200
400
600
800
1000
1200
Hardness
0
1
2
3
4
5
6
Iron
0
30
60
90
120
150
180
Magnesium
Manganese
0.0
0.2
0.4
0.6
0.8
1.0
Nickel

Figure D-1. Continued.

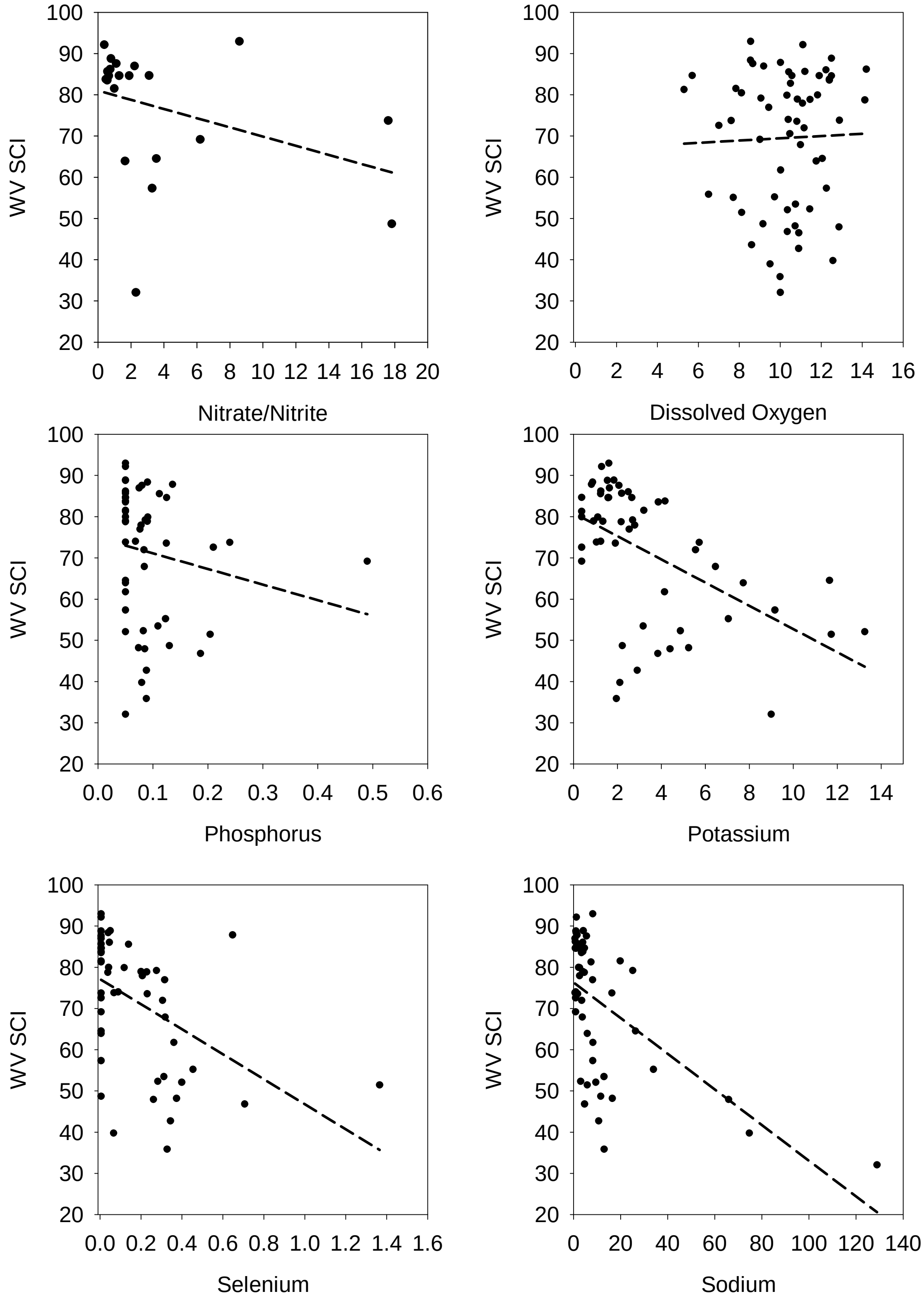

Figure D-1. Continued.

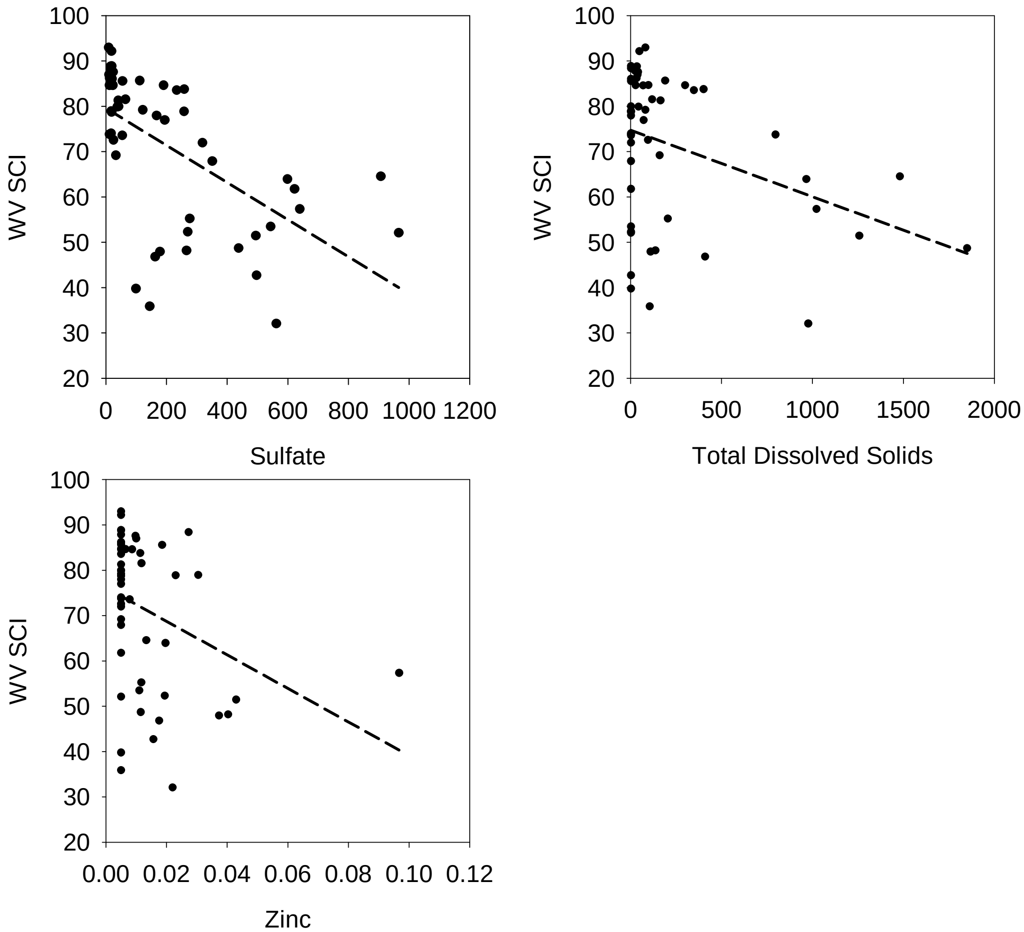

Figure D-1. Continued.

APPENDIX E
STANDARDIZATION OF DATA AND METRIC CALCULATIONS

Standardization and Statistical Treatment of MTM/VF Fish Data

Fish Sample Collection Methods

Fish communities, like benthic communities, respond to changes in their environment. Some fish species are less tolerant of degraded conditions; as stream health decreases, they will either swim away or perish. Other species are more tolerant of degraded conditions, and will dominate the fish community as stream health declines.

Fish are collected using a backpack electrofisher. In electrofishing a sample area, or “reach”, is selected so that a natural barrier (or a block net, in the absence of a natural barrier) prevents fish from swimming away upstream or downstream. An electrical current is then discharged into the water. Stunned fish float to the surface and are captured by a net, and held in buckets filled with stream water. The fish are identified, counted and often measured and/or weighed. Three passes are made with the electrofisher to collect all the fish in the selected stream reach. After the three passes are complete and the fishes have recovered, they are released back to their original habitat. Some fish may be retained as voucher specimens. The data collected from the three passes are composited into a single sample for the purposes of the MTM-VF project.

Pennsylvania State University (PSU) conducted fish sampling for USEPA. PSU collected fish from 58 sites located on first through fifth order streams in West Virginia. Fish were also sampled by REIC, Potesta, and BMI, following the same protocols. The only exceptions were five samples taken by REIC that were made with a pram electrofisher. In a pram unit, the electrofishing unit is floated on a tote barge rather than carried in a backpack. Otherwise, the pram samples followed the same protocols.

The Mid-Atlantic Highland IBI

The Mid-Atlantic Highland Index of Biotic Integrity, or IBI, (McCormick et al. 2001), provides a framework for assessing the health of the fish community, which, like the WV SCI, indicates the overall health of a stream. The IBI was developed and calibrated for the Mid-Atlantic Highlands using samples from several Mid-Atlantic states, including West Virginia. The IBI is a compilation of scores from nine metrics that are responsive to stress (Table E-1).

Table E-1. Metrics included in the Mid-Atlantic Highland IBI, with descriptions and expected response to increasing degrees of stress.

Metric	*Metric Description*	*Predicted Response to Stress*
Native Intolerant Taxa	**Number of indigenous taxa that are sensitive to pollution; adjusted for drainage area**	**Decrease**
Native Cyprinidae Taxa	**Number of indigenous taxa in the family Cyprinidae (carps and minnows); adjusted for drainage area**	**Decrease**
Native Benthic Invertivores	**Number of indigenous bottom dwelling taxa that consume invertebrates; adjusted for drainage area**	**Decrease**
Percent Cottidae	**Percent individuals of the family Cottidae (sculpins)**	**Decrease**
Percent Gravel Spawners	**Percent individuals that require clean gravel for reproductive success**	**Decrease**
Percent Piscivore/Invertivores	**Percent individuals that consume fish or invertebrates**	**Decrease**
Percent Macro Omnivore	**Percent individuals that are large and omnivorous**	**Increase**
Percent Tolerant	**Percent individuals that are tolerant of pollution**	**Increase**
Percent Exotic	**Percent individuals that are not indigenous**	**Increase**

Watershed Standardization

In nature, larger watersheds are naturally more diverse than smaller watersheds. Not surprisingly, this was found to be true in the MTM-VF project. To ensure that differences among fish communities are due to differences in stream health and not from the natural effect of watershed size, three richness metrics were standardized to a 100km^2 watershed.
This standardization applies only to the three richness metrics; percentage metrics are not affected by watershed size and required no adjustment before scoring.

The regression equations used in the watershed standardization were developed by McCormick et al. 2001. They studied the relationship between watershed size and fish community richness in minimally stressed sites, and derived equations that predict the number of taxa that would be expected in a healthy stream of a given watershed size. The equations were not published in the original 2001 paper, but were obtained from McCormick in a personal communication.

First, the predicted numbers of taxa were calculated using the regression equations. Then residual differences were calculated:

Residual difference = Actual number in sample – Predicted number

Finally, an adjustment factor was added to the residual difference (see Table E-2), depending on the richness metric.

Table E-2. Regression equations and adjustment factors for standardizing richness metrics to a 100 km2 watershed. (McCormick, personal communication)

Richness Metric	*Regression Equation*	*Adjustment Factor*
Native Intolerant Taxa	**predicted = 0.440071 + 0.515214 * Log_{10} (Drainage Area [km^2])**	**1.470**
Native Cyprinidae Taxa	**predicted = 0.306788 + 2.990011 * Log_{10} (Drainage Area [km^2])**	**6.287**
Native Benthic Invertivores	**predicted = 0.037392 + 2.620796 * Log_{10} (Drainage Area [km^2])**	**5.279**

Metric Scoring and IBI Calculation

After the necessary watershed adjustments had been made, metric scores were applied to the adjusted richness metrics and the raw percentage metrics. The scoring regime was originally derived from the distribution characteristics of the large Mid-Atlantic Highlands data set upon which the IBI was calibrated (McCormick et al. 2001).

Some metrics decrease in value with increasing stress, such as the richness metrics. For example, the number of intolerant species (those sensitive to poor water quality) decreases as stream health declines. Each of the metrics that decreases in value with increasing stress was given a score ranging from 0 – 10 points. Zero points were given if the adjusted value was less than the 5^{th} percentile of McCormick's non-reference sites; 10 points were given if the adjusted value was greater than the 50^{th} percentile of McCormick's high quality reference sites. Intermediate metric values, those between 0 and 10, were interpolated between the two end points.

Other metrics increase in value with increasing stress, such as the percent of tolerant fish species. As stream health declines, only the tolerant species thrive. Metrics that increase in value with increasing stress are also given a score ranging from 0 to 10. A score of 0 points is given to values greater than the 90^{th} percentile of McCormick's non-reference sites. A score of 10 points are given to values less than the 50^{th} percentile of McCormick's moderately restrictive reference sites. Intermediate metric values were scored by interpolation between 0 and 10.

After all nine metrics have been scored, they are summed. Nine metrics scoring a possible 10 points each equals a possible maximum of 90 points; to convert to a more easily understood 100-point scale, the raw sum score is multiplied by 1.11. The Mid-Atlantic Highlands IBI is this resulting number, on a scale of 0-100 (Table E-3).

Table E-3. Mid-Atlantic Highland IBI: Metric scoring formulas. Richness metrics were adjusted for drainage area before calculating scores.

Metric	*Scoring formulas (X=metric value)*
Native Intolerant Taxa (Adjusted for watershed)	**If X>1.51, then 10. If X<0.12, then 0. Else 10*X/1.39**
Native Cyprinidae Taxa (Adjusted for watershed)	**If X>6.24, then 10. If X<1.54, then 0. Else 10*X/4.70**
Native Benthic Invertivore Taxa (adjusted for watershed)	**If X>5.34, then 10. If X<1.27, then 0. Else 10*X/4.07**
Percent Cottidae	**If X>7, then 10. Else 10*X/7**
Percent Gravel Spawners	**If X>72, then 10. If X<21.5, then 0. Else 10*X/50.5**
Percent Piscivore/Invertivores	**If X>9, then 10. Else 10*X/9**
Percent Macro Omnivore	**If X>16, then 0. If X<0.2, then 10. Else 10*(16-X)/15.8**
Percent Tolerant	**If X>97, then 0. If X<28, then 10. Else 10*(97-X)/69**
Percent Exotic	**If X>24, then 0. If X<0.2, then 10. Else 10*(24-X)/23.8**
SUM of all 9 metric scores	**Raw Score**
Mid-Atlantic Highland IBI score (0-100 range)	**Raw Score x 1.11**

Standardization and Metric Calculations of Benthic Data

Benthic Sample Collection Methods

What do we know about healthy Appalachian streams? There are many species of organisms that live in streams (insects, crustaceans, mussels, worms), and in general, healthy streams have a greater variety of animals than unhealthy streams. Three groups of insects in particular, the mayflies, stoneflies, and caddisflies, are sensitive to pollution and degradation and tend to disappear as a stream's water quality decreases. Other insect groups are more tolerant to pollution, and tend to increase as a percentage of the total benthic (bottom-dwelling) communities in unhealthy streams. In order to determine whether a stream is healthy or unhealthy, we must obtain a representative estimate of the variety and identity of species in the stream.

How do biologists sample stream communities to get a representative and precise estimate of the number of species? First, we must know where the organisms live in the stream. An Appalachian stream bottom is not a uniform habitat: there are large rocks, cobble, gravel, patches of sand, and tree trunks in the streambed. Each of these is a microhabitat and attracts species specialized to live in the microhabitat. For example, some species live on the tops of rocks, in the current, to catch food particles as they drift by. Some species crawl around in protected areas on the underside of rocks; some cling to fallen tree trunks or branches; yet others live in gravel or sand. Clearly, if we sample many microhabitats, we will find more species than if we sample only one. In order to characterize the stream section, we need to sample a large enough area to ensure that we have sampled most of the microhabitats present.

How do we “measure” the biological effects of human activities, such as mining, on stream ecosystems? What is the unit of the stream that we characterize? Typically, we wish to know the effects on a wide variety of organisms throughout the stream. However, sampling everything is expensive and potentially destructive. Selecting a single, common habitat that is an indicator of stream condition is analogous to a physician measuring fever with an oral thermometer at a single place (the mouth). Therefore, biologists selectively sample riffles, which are prevalent in Appalachian streams, and are preferred habitat for many sensitive species. When we sample a riffle, we wish to characterize the entire riffle, not just an individual rock or patch of sand, and sampling must represent the microhabitats present. By taking several samples, even with a relatively small sampling device such as a Surber Sampler, we can ensure that enough microhabitats have been sampled to obtain an accurate estimate of diversity in the stream.

Sampling Gear

Sampling also depends on the gear and equipment that biologists use to capture organisms. Small samplers and nets can be easily and economically handled by one or two persons; larger sampling equipment requires larger crews. In the MTM-VF project, the sampling protocol calls for 6 Surber samples (0.09 square meter each, for 0.56 square meter total from each site), or 4 D-frame samples (0.25 square meter each, for 1 square meter from each site). If the Surber or D-frame grabs are spread out throughout the riffle (preferably in a random manner), then they will adequately represent most of the microhabitats present, and total diversity of the riffle can be characterized.

Standardization of data

Many agencies were involved in the collection of data for the Mountain Top Mining Environmental Impact Statement. Not all organizations used the same field sampling methods, and during the two-year investigation, some organizations changed their sampling methods. In order to "compare apples to apples," it is necessary to standardize the data, so that duplicate samples taken using different methods will yield the same results after standardization.

We begin here with a description of the sampling methods used, a general discussion of sampling, analysis of a set of paired samples using two methods, and finally the specific steps used to standardize the samples from the different organizations.

MTM/VF Benthic Sampling Methods

The two methods used in the MTM/VF study, which we term the "D-frame method" and the "Surber method," differ in sampling gear and in the treatment of the collected material. The methods are compared below.

D-frame Method

Equipment: A D-frame net is a framed net, in the shape of a "D", which is attached to a pole.

Procedure: The field biologist positions the D-frame net on the stream bottom, then dislodges the stream bottom directly upstream to collect the stream-bottom material, including sticks and leaves, and all the benthic organisms. The net is 0.5 meter wide, and $0.25m^2$ area of streambed is sampled with each deployment. In the MTM/VF study, the net was deployed 4 times at each site, for a total area of 1.0 m^2.

Compositing: All the collected materials were composited into a single sample.

Subsampling: Samples collected in the D-frame method are often quite large, and two organizations "subsampled" to reduce laboratory processing costs. In subsampling, the samples are split using a sample splitter (grid), and a subsample consisting of 1/8th (or, in the case of samples with few organisms, 1/4th or 1/2) of the original material was analyzed. All organisms in the subsample were identified and counted.

Surber Method

Equipment: A Surber sampler is a square frame, covering 1 square foot ($0.093m^2$) of stream bottom.

Procedure: The Surber is placed horizontally on cobble substrate in shallow stream riffles. A vertical section of the frame has the net attached and captures the dislodged organisms from the sampling area.
In the MTM/VF study, the Surber sampler was deployed 3 to 6 times at each site, for a total area sampled of 3 to 6 square feet (0.28 to $0.56m^2$).

Compositing: The materials collected were not composited, but were maintained as discrete sample replicates.

Subsampling: The materials collected in each of the Surbers were not subsampled. All organisms were identified and counted.

The D-frame sampler was most consistently used by participants. EPA and Potesta used only D-frame sampling; BMI used only D-frame sampling in the first two sets of samples, and afterwards used both Surber and D-frame samplers. REIC collected both Surber and D-frame samples throughout the study. The various methods used by the organizations participating in the MTM/VF study are summarized in Table E-4.

Table E-4. A comparison of each organization's methods of collecting and compositing samples, and laboratory subsampling protocols.

Organization	*Sample Method*	*Compositing*	*Subsampling*
USEPA	4 times 1/4m^2 D-frame net	Composited samples	1/8 of original sample. If abundance was low, the laboratory subsampled to 1/4 or ½ of the original sample, or did not subsample at all.
REIC (Twelvepole Creek)	3 times Surber and 4 times 1/4m^2 D-frame net	All Surber samples were analyzed separately (no compositing). Composited samples.	The D-frame samples were subsampled to 1/4 of original sample if necessary. All 7 samples were combined for reporting, representing approximately 1.3 m^2 of stream bottom.
Potesta (Twenty Mile Creek)	4 times 1/4 m^2 D-frame net.	Composited samples	Not subsampled; counted to completion.
BMI (Twenty Mile Creek)	Fall 1999 and Spring 2000: 4 times 1/4 m^2 D-frame net. Fall 2000, 6 times Surber, and four times 1/4 m^2 D-frame net. Spring 2001, 4 times Surber and four times 1/4m^2 D-frame sample**.**	Composited samples. Surber samples kept separate. D-frame samples were composited. Surber samples kept separate. D-frame samples were composited.	Not subsampled; counted to completion. Not subsampled; counted to completion. Not subsampled; counted to completion.
BMI (Island Creek):	Fall 1999 and Spring 2000, four times 1/4 m^2 D-frame net, Fall 2000, 4 times Surber, kept separate, and four times 1/4 m^2 D-frame net, composited. Spring 2001: No data.	Composited samples. Surber samples were kept separate. D-frame samples were composited.	Not subsampled; counted to completion. Not subsampled; counted to completion.

Treatment of Sampler Data

How do we treat data from the samplers? A common method is to take the average of measures from several (4 or 6) samplers. The problem with this approach is that we know that each sampler, individually, underestimates species richness of the stream site; thus the average of underestimates will also be an underestimate (see Table E-5). In addition to species (or family) richness, a measure important in the West Virginia Stream Condition Index, and in many other similar condition indexes, is the degree to which a community is dominated by the most abundant species found. In degraded streams, communities are often dominated by one or a few species tolerant of poor habitat or poor water quality. In a healthy stream, dominance over the entire community is low. However, a single microhabitat, such as a large rock, is likely to by dominated by one or two species adapted to that microhabitat. A different species will be dominant in a sand habitat. The entire riffle is diverse and has low dominance when we consider several microhabitats. Thus, if we calculate the average dominance over several small sampling devices, such as Surbers, we overestimate community dominance. Each Surber sample may be highly dominated by a different species, yet the overall community may not dominated by any of those species. This is shown with data from one of the sites (Table E-5): average richness of Surbers is lower than richness of the composited Surbers (representing the entire riffle). Average dominance of the Surbers is higher than the composited sample. By averaging, this site appears to be in poorer condition than it really is, especially if compared to West Virginia's Stream Condition Index.

Standardizing Sampling Effort

Sampling effort is a combination of the total riffle area sampled, the heterogeneity of the stream bottom sampled, and the number of organisms identified. As previously discussed, a composited sample that consists of several smaller samples from throughout the riffle area will adequately characterize the abundances and relative abundances of most of the common species at a site. It will not, however, necessarily characterize all of the rare species at a site (those making up less than about 2% of the total community). Sampling to collect all rare species is prohibitively expensive and destructive of the riffle. But we must consider the effects of rare species since they contribute to diversity and richness measures in proportion to sampling effort. For example, the D-frame net, which covers 1 m^2, (10.8 square feet) will capture more rare species than 4 or 6 Surber samplers, which cover only 0.37 m^2 (4 square feet) and 0.56 m^2 (6 square feet) respectively. By the same token, subsampling, or counting only a portion of the total sample, also undercounts rare species.

Fortunately, it is relatively easy to standardize sampling effort among different sampling methods so that the bias is removed. Standardization is done by adjusting taxa counts to expected values for subsamples smaller than an original sample, using the following binomial probabilities for the capture of each taxon (Hurlbert 1971; Vinson and Hawkins 1996).

$$E(S_n) = \sum_i \left[1 - \frac{\binom{N - N_i}{n}}{\binom{N}{n}} \right]$$

= The expected number of species in a sample of n individuals selected at random from a collection containing N individuals, S species, and N_i individuals in the ith species.

Taxa counts (number of species or families) can only be adjusted down to the level of the smallest sampling effort in the data set; it is not possible to estimate upwards (and effectively "make up" data). In the MTM/VF data, benthic samples were standardized to 200 individuals, which is the standard WV SCI practice, and to 100 individuals, to accommodate those samples that contained less than 200 organisms. Individual taxa are not removed from a sample in the standardization process; only the taxa counts are standardized. Estimates of abundance per area and relative abundance are unaffected by sampling effort, and are not adjusted.

Table E-5. Six Surber replicates from site MT-52 (Island Creek), Fall 1999. The dominant family for each Surber is in bold, outlined with a heavy line. The subdominant family is outlined with a light line. Either Taeniopterygidae or Nemouridae are dominant in each Surber, but they tend not to co-occur in the same Surber. Metrics are shown at the bottom.

			Surber					
Order and family	A	B	C	D	E	F	Composite	
Beetles								
Elmidae	11	13	3	3	14		44	
Psephenidae	6	2	4	4	9		25	
Caddisflies								
Hydropsychidae	13		4	6	8	11	42	
Philopotamidae			1	2			3	
Polycentropodidae				8	5		13	
Rhyacophiloidea	8	8	4			6	26	
Uenoidae	1	2			5	3	11	
Mayflies								
Ameletidae	11		1			19	31	
Baetidae		3	1	5	18		27	
Baetiscidae	1						1	
Ephemerellidae	3	6	4	3	16	10	42	
Heptageniidae		2					2	
Stoneflies								
Chloroperlidae	1					1	2	
Nemouridae	**50**		**61**			**24**	135	
Perlidae		1					1	
Perlodidae		23		1			24	
Taeniopterygidae		**71**	1	**25**	**95**		**192**	
True flies								
Chironomidae	25	26	15	7	11	9	93	
Empididae				1			1	
Simuliidae	2	4	1	3	1		11	
Tipulidae	5			4		2	11	
Other	2		2	1	6	2	13	
metrics	A	B	C	D	E	F	Composite	Average
Total Individuals	139	161	102	73	188	87	750	125
Number of Families	15	12	14	14	12	11	25	13
Dominance (1)	0.36	0.44	0.60	0.34	0.51	0.28	0.26	0.42
Dominance (2)	0.54	0.60	0.75	0.45	0.60	0.49	0.44	0.57
Dominant family	Nemou	Taeniop	Nemou	Taeniop	Taeniop	Nemou	Taenioptery	?
Subdominant family	Chirono	Chirono	Chirono	Polycen	Baetida	Ameleti	Nemourida	?

Comparison of Paired Samples

We analyzed matched data collected by EPA and Potesta Associates at 21 sites in Island Creek, Mud River, and Spruce Fork over 3 sampling periods from Summer 1999 to Winter 2000. EPA sampled using its D-frame method described above, and Potesta used the 6-Surber method described above. EPA also took an additional 21 samples using both methods, at 10 different sites. Sample crews visited sites simultaneously. The objective of this analysis was to determine the comparability of samples collected using two different methods. If sample pairs collected in both ways, at the same site and time, show no bias relative to each other, then the two sampling methods would be considered comparable and valid for assessments.

Figure E-1 shows the cumulative number of families in 6 Surbers at 5 representative sites, showing that each successive Surber captures new families not captured by the previous Surbers.

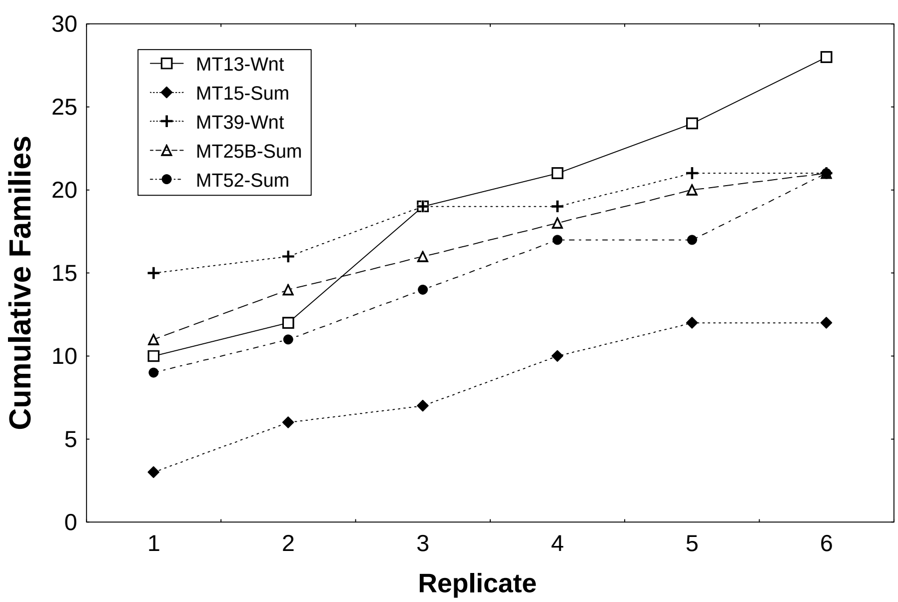

Figure E-1. Cumulative number of families identified in successive Surber samplers from 5 MTM sites.

If we consider the number of organisms captured per unit area of the stream bottom, the 2 methods are unbiased. Figure E-2 compares the individuals per square meter as estimated using Surbers, with individuals per square meter estimated using D-frame samples. The diagonal dotted line represents exact agreement (1:1). While there is scatter about the line, there is no bias above or below the line. Note that Potesta and EPA samples overlap and are unbiased with respect to each other.

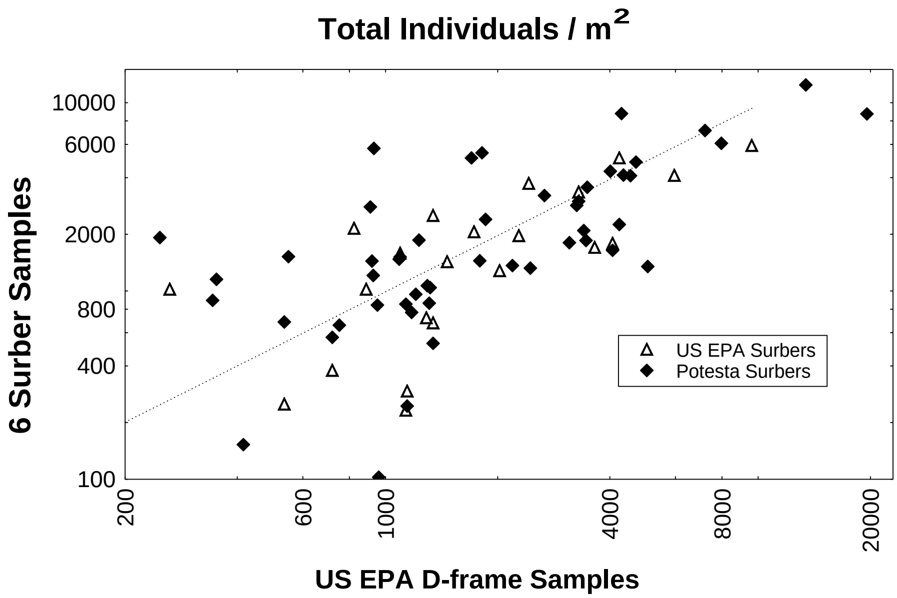

Figure E-2. Total number of individuals from 6 Surber samplers and from EPA D-frame samples. Each point represents a comparison of Surber and D-frame results from the same site at the same time. The vertical axis is the Surber results, and the horizontal axis is the D-frame results. The dotted line is the 1:1 slope of exact agreement between methods. Potesta Surber results are shown with solid diamonds; EPA Surbers with open triangles. All D-frame samples were from EPA.

As explained above, calculating the average number of families from 6 Surbers underestimates richness, since each individual Surber underestimates richness. This is shown graphically in Figure E-3. The average number of families from the Surbers is shown on the vertical axis, and the total families from the D-frame on the horizontal axis. Nearly all the points lie below the 1:1 line. The average bias is approximately 5 families. If we plot the total, cumulative families using Surbers against those using D-frames (Figure E-4), then the D-frames underestimate relative to the Surbers by about 5 taxa, because the D-frames were subsampled to 1/8th the total sample volume. However, if both Surber and D-frame samples are composited and standardized to a constant number of organisms (200), then there is no bias in the family richness (Figure E-5). Note also in Figure 5 that the scatter of points about the 1:1 line is much smaller than for the unstandardized data shown in Figures 3 and 4, and that both Potesta and EPA Surber are unbiased to each other (note 2 symbols in figure).

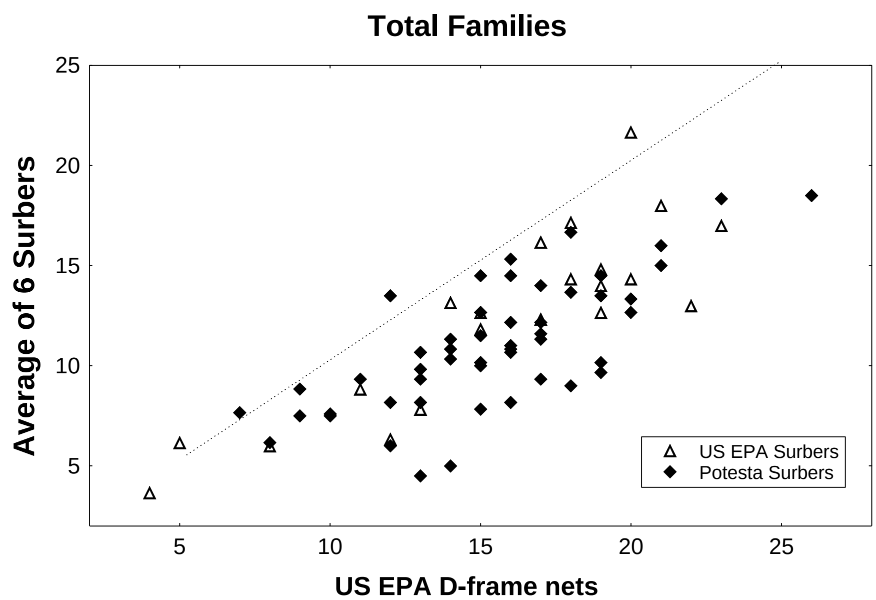

Figure E-3. Number of families per site, averaged over 6 Surbers (vertical), against total numbers from D-frame samples. See Figure 2 caption.

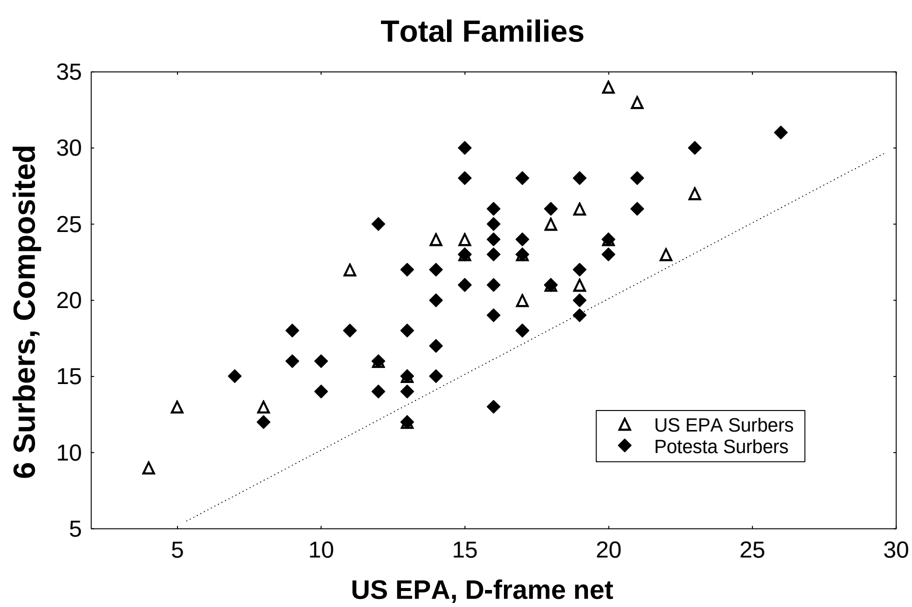

Figure E-4. Total families per site, from composite of 6 Surbers (cumulative), compared to EPA D-frame results. As in Figures 2 and 3.

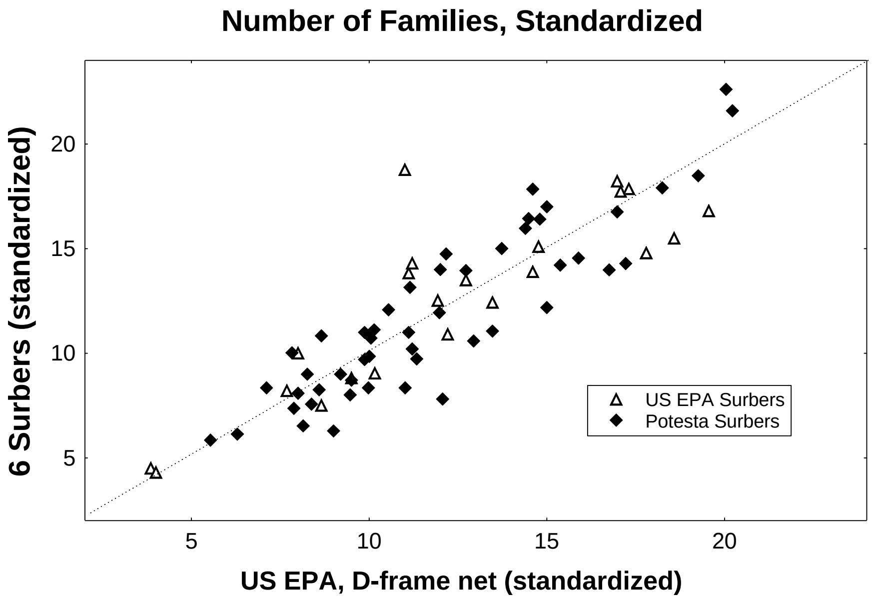

Figure E-5. Number of taxa in standardized Surber samples (vertical) compared to standardized D-frame samples (horizontal). As in Figures 2-4.

The West Virginia Stream Condition Index (WV SCI) is calculated from 6 metric scores. When the index was developed, the scoring formulas were calibrated to a 200 organism sample (Gerritsen et al. 2000). If samples were larger than 200 organisms, they were standardized before the scoring formulas were applied.

Summary: Standardization of Benthic Data

In summary, the data collected by the participants differed in sampling, subsampling and reporting methods. Despite the differences, any one of these sampling, subsampling, and reporting methods is unbiased with respect to the types of organisms collected (all used the same mesh size), the density of organisms (numbers per unit area), and the relative abundances (percent of community). The only bias is that of the number of families (taxa richness) as affected by sampling effort. Sampling effort is a combination of the total area sampled, the heterogeneity of the stream bottom sampled, and the size of the subsample. Since all participants used the same field methods for the D-frame samples, 4 D-frames in the field, use of the D-frame data standardizes the field sampling effort. However, EPA subsampled to $1/8^{th}$ of the total material (with some exceptions noted in the data); REIC to $1/4^{th}$ the total material (with some exceptions); and all others counted the entire sample. Therefore, taxa richness was standardized to be equivalent to a subsample of $1/8^{th}$ the total, original material. Unfortunately, REIC data was reported as combined D-frame and Surber samples and could not be standardized for both sampling effort and subsampling in the laboratory.

Metric Calculations for Benthic Data

The West Virginia Stream Condition Index (WV SCI) rates a site using an average of six standard indices, or metrics, each of which assesses a different aspect of stream health.

The WV SCI metrics include:

- Total Taxa – a count of the total number of families found in the sample. This is a measure of diversity, or richness, and is expected to increase with stream health.
- Number of EPT Taxa – a count of the number of families belonging to the Orders Ephemeroptera (mayflies), Plecoptera (stoneflies), or Tricoptera (caddisflies) Members of these three insect orders tend to be sensitive to pollution. The number tends to increase with stream health.
- Percent EPTs (Number of EPT families / Total number of Families) - this measures the contribution of the pollution-sensitive EPT families to the total benthic macroinvertebrate community. It tends to increase with stream health.
- Percent Chironomidae – the percentage of pollution-tolerant midge (gnat) larvae in the family Chironomidae tends to decrease in healthy streams and increase in streams that are subjected to organic pollution.
- Percent 2 dominant families - a measure of diversity of the stream benthic community. This metric tends to decrease with stream health.
- Hilsenhoff Biotic Index (HBI). The HBI assigns a pollution tolerance value to each family (more pollution-tolerant taxa receive a higher tolerance value). Tolerance values were found in the literature (Hilsenhoff 1987, Barbour et al. 1999) or were assigned by EPA biologists from Wheeling, WV or Cincinnati, OH. The HBI is then calculated by averaging the tolerance values of each specimen in a sample. The HBI tends to increase as water quality decreases

Several taxa were excluded from the analysis because they inhabit terrestrial, marginal, or surface
areas of the stream. The excluded taxa included Aranae, Arachnida, Collembola, and Cossidae.

After all the benthic data had been migrated to EDAS, and after all the data had been collapsed to the Family level, the six WV SCI metrics were calculated from composited enumerations, or counts.

Metric Scoring and Index Calculation

As discussed previously, richness metrics are affected by sampling effort, and were therefore standardized to a 100 or 200 organism subsample before scoring. Other WV SCI metrics are independent of sampling effort and did not require standardization. Each of the metrics was then scored on a scale of 0 to 100 using scoring formulae derived for 100 and 200 organism subsamples (Table E-6). The WV SCI was calculated as an average of the six metric scores.

Table E-6. WV SCI: Metric scoring formulas. The richness metrics have two scoring formulas each, depending on the standardized sample size (100 or 200 organisms). The

scoring formulas are from unpublished analyses for 100 organism richness metrics and Gerritsen et al. (2000) for 200 organism richness metrics and other metrics.

Metrics that decrease with stress	*Scoring formulas (X=metric value)*	
Total taxa	**$Score_{100}$ = 100 × (X/18),**	**$Score_{200}$ = 100 × (X/21)**
EPT taxa	**$Score_{100}$ = 100 × (X/12),**	**$Score_{200}$ = 100 × (X/13)**
% EPT	**score = 100 × (X/91.9)**	
Metrics that increase with stress		
%Chironomidae	**score = 100 × [(100-X)/(100-0.98)]**	
% 2 dominant	**score = 100 × [(100-X)/(100-36.0)]**	
HBI	**score = 100 × [(10-X)/(10-2.9)]**	

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Environmental Impact Study of Mountaintop Mining and Valley Fill Operations in West Virginia

Aquatic Impacts Study

July 16, 2002

Briefing for EIS Steering Comitteee

Overview of Briefing

- Aquatic Impacts Study
- ORD/NERL Involvement
- Biological Indices
- EIS Results
  - Fish
  - Macroinvertebrates
- Summary

Aquatic Impacts Study Objectives

- Is the biological condition of streams in areas with MTM/VF operations degraded compared to the condition of streams in un-mined areas?
- Are there “additive” biological impacts in streams where multiple fills are located?

Aquatic Impacts Study

- Region III initiated the aquatic impacts study to support the overall EIS
- Spring 1999 to Winter 2000
- Field collections
  - Fish
  - Macroinvertebrates
  - Habitat
  - Water chemistry

ORD/NERL Involvement

- Three reasons:
  – Region III was criticized for descriptive only analysis of macoinvertebrate data
  – Penn State/Region III presented fish data using an index calibrated for larger streams (OEPA)
  – Mining company monitoring data was not included in EIS

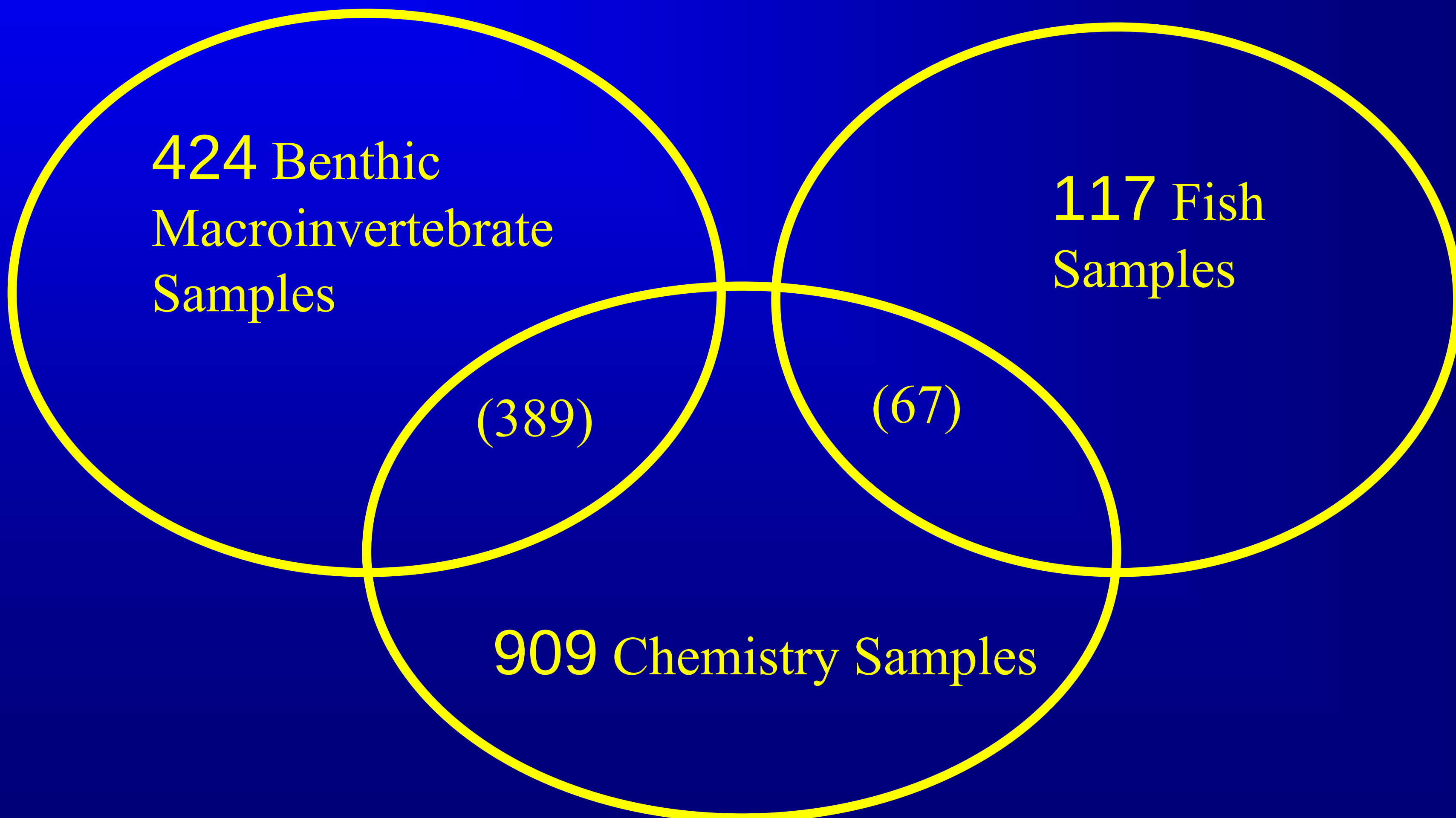
ORD/NERL Involvement

- Assembled database of Region III, Penn State and mining company data
- Analyzed fish and macroinvertebrate data separately to address study objectives
- Provide report to EIS steering committee for inclusion in the overall EIS

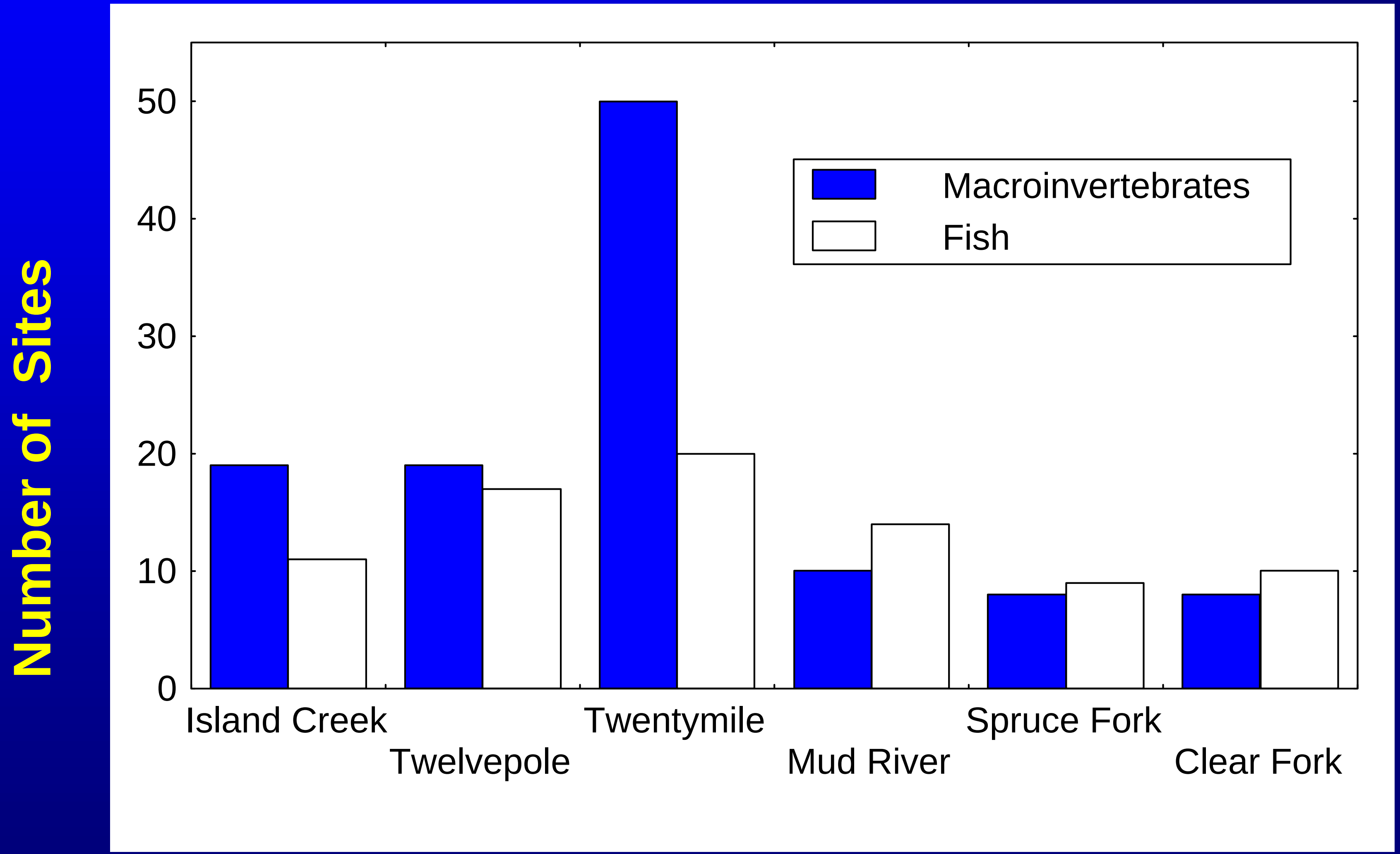
Mining Company Data

- Fish, macroinvertebrate, water chemistry, habitat and field chemistry
- Pen Coal, Arch, Massey, Fola
- Twentymile, Island Creek and Twelvepole

Sample Size

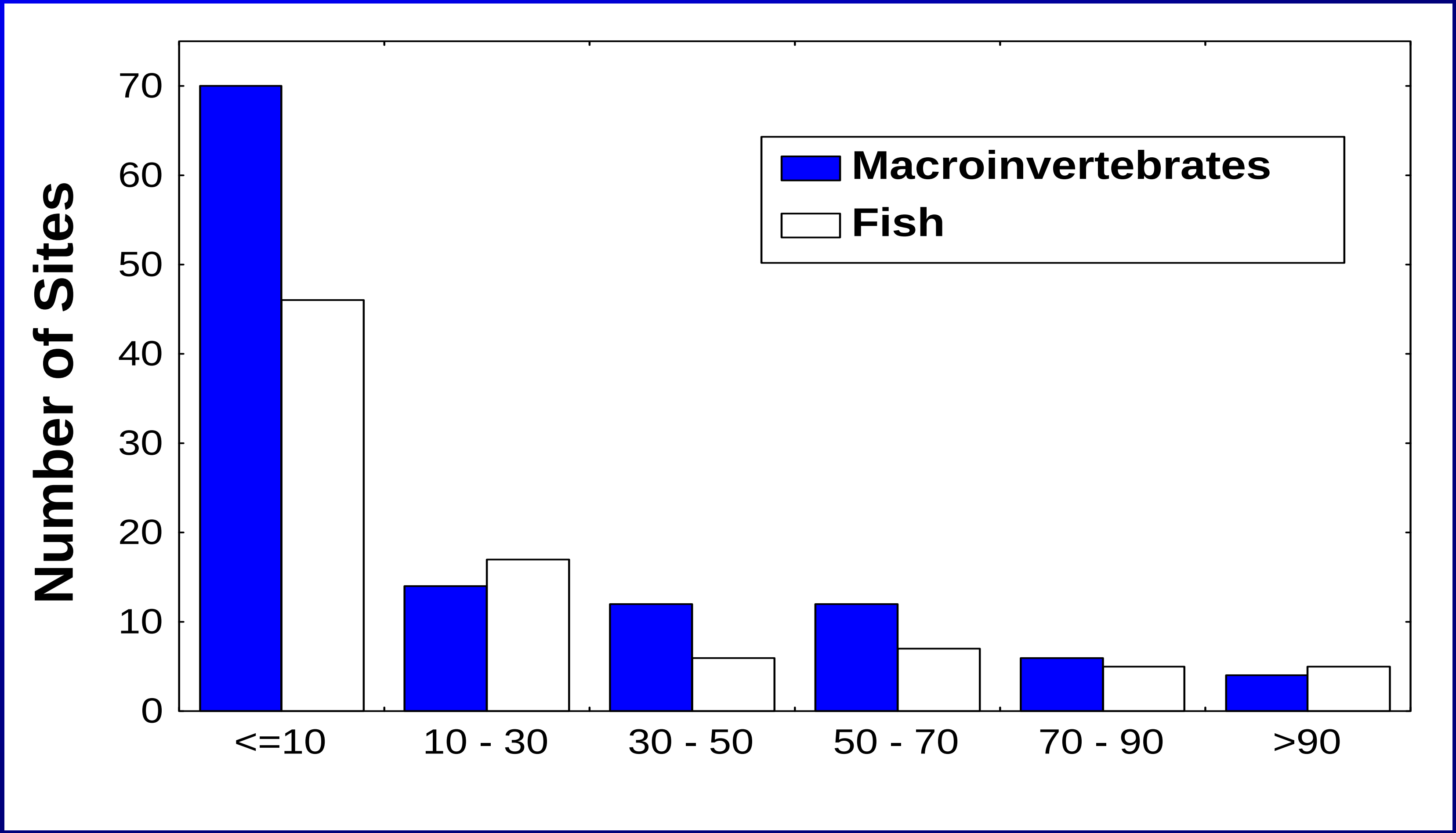

424 Benthic
Macroinvertebrate
Samples
117 Fish
Samples
(389)
(67)
909 Chemistry Samples

Sample Size By Watershed



Sample Size

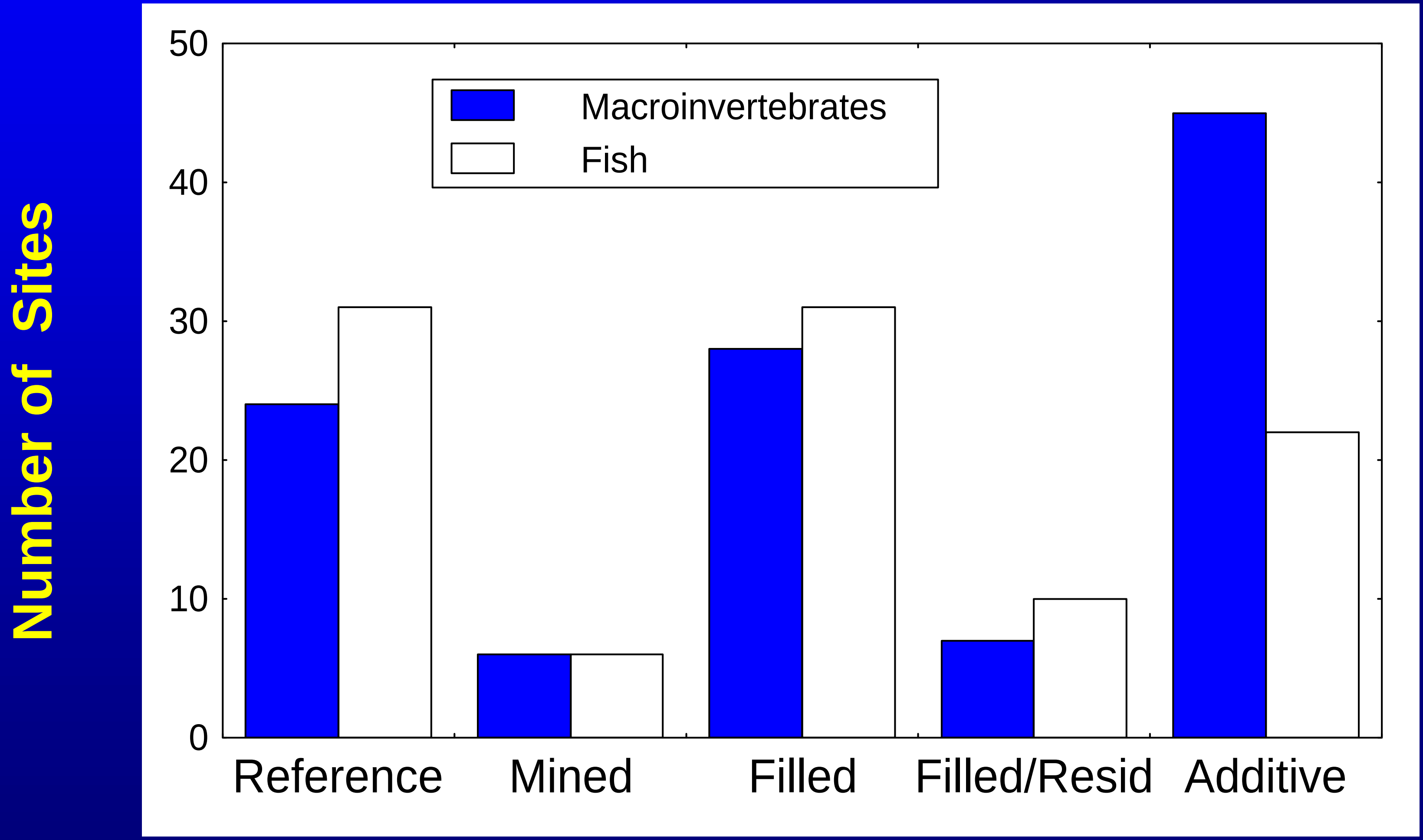
by Subwatershed Area (sq km)



Site Classes

- Regional reference
- Unmined – no mining activity (EIS)
- Filled - one or more valley fills (EIS)
- Mined - mined by other methods (EIS)
- Filled/Residential – fills and residential land use (EIS)
- Additive – multiple sources

Sample Size By Site Type



How should we assess biological condition?

- Biological indices:
  - Compare the diversity, composition, and functional organization of a stream community to those of natural streams in the region
  - Recommended in EPA Guidance
    - Biological Criteria: National Program Guidance for Surface Waters (EPA-440/5-90-004), April 1990
    - CALM: Consolidated Assessment and Listing Methodology
- As of 1995, 42 states are using biological indices to assess impacts to streams

Biological Indices for MTM/VF EIS
(off-the-shelf)

- West Virginia Stream Condition Index (WVSCI) for invertebrates (Gerritsen et al. 2000)
- Mid-Atlantic Highlands IBI for fish (McCormick et al. 2001)

Aquatic Impacts Study Objectives Revisited

Is the biological condition of streams in areas with MTM/VF operations degraded compared to the condition of streams in un-mined areas?

- One-way analysis of variance to test for differences among all EIS classes (alpha = 0.05)
- Least square means test to compare Unmined sites vs. Filled, Filled & Residence, and Mined sites (alpha = 0.01)

Aquatic Impacts Study Objectives Revisited

Are there "additive" biological impacts in streams where multiple fills are located?

- Descriptive measures, Spearman correlations and linear regressions with stream mile along the main stem in two watersheds

Results of Fish Analysis

Fish IBI Metrics

- Differentiate between reference and stressed samples
- Represent different aspects of the community (taxonomic, trophic, reproductive, tolerance)
- Adjusted for watershed area

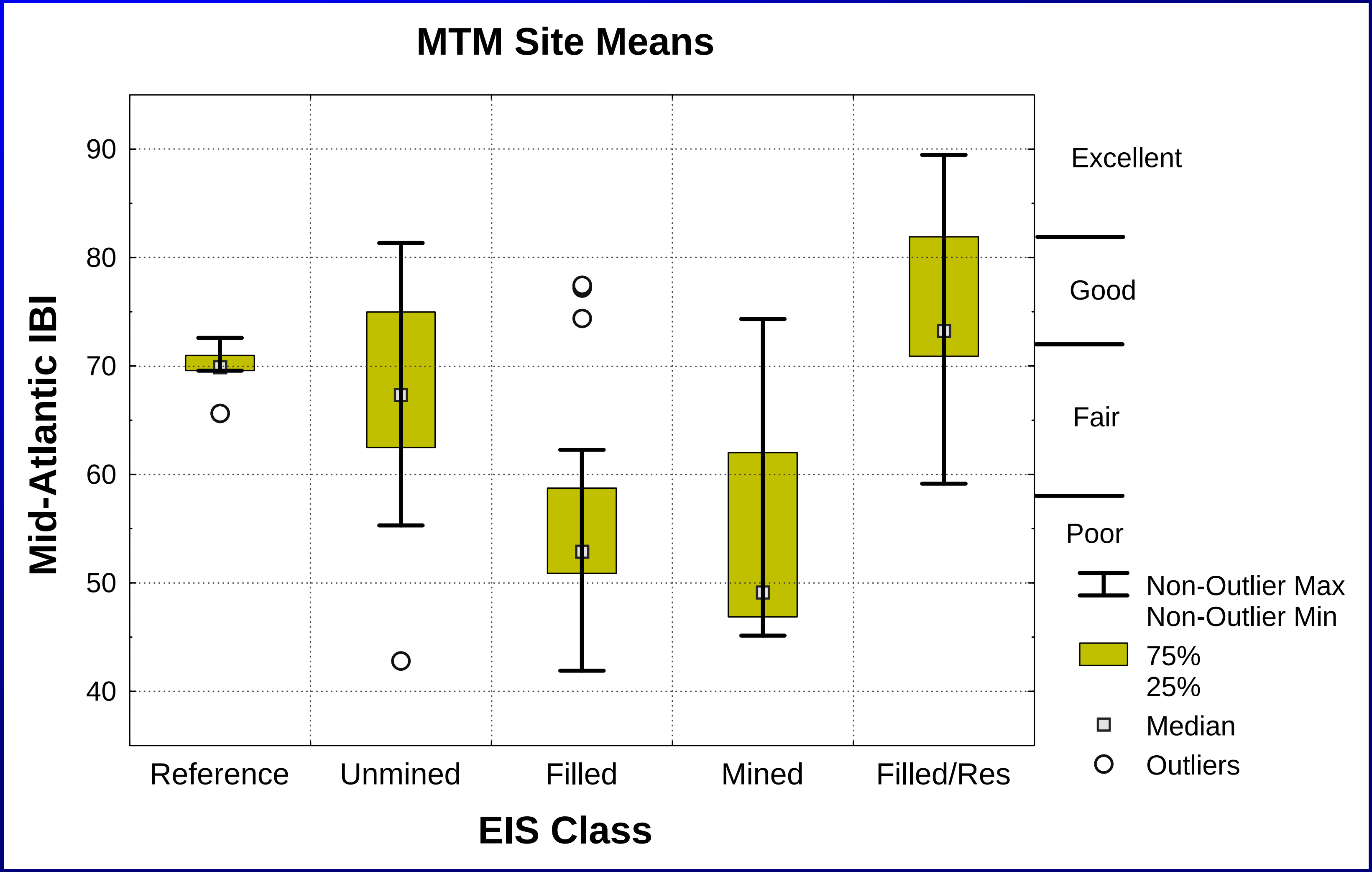
✓ Intolerant species
✓ Native minnow species
✓ Native benthic invertivore species
✓ % Sculpin individuals
✓ % Gravel spawning individuals
✓ % Piscivore/invertivore individuals
✓ % Macro-omnivore individuals
✓ % Tolerant individuals
✓ % Exotic individuals

Analysis of Fish Data

- No one season had sufficient fish data for analysis.
- Site averages of the IBI and component metrics were primary analysis endpoints.

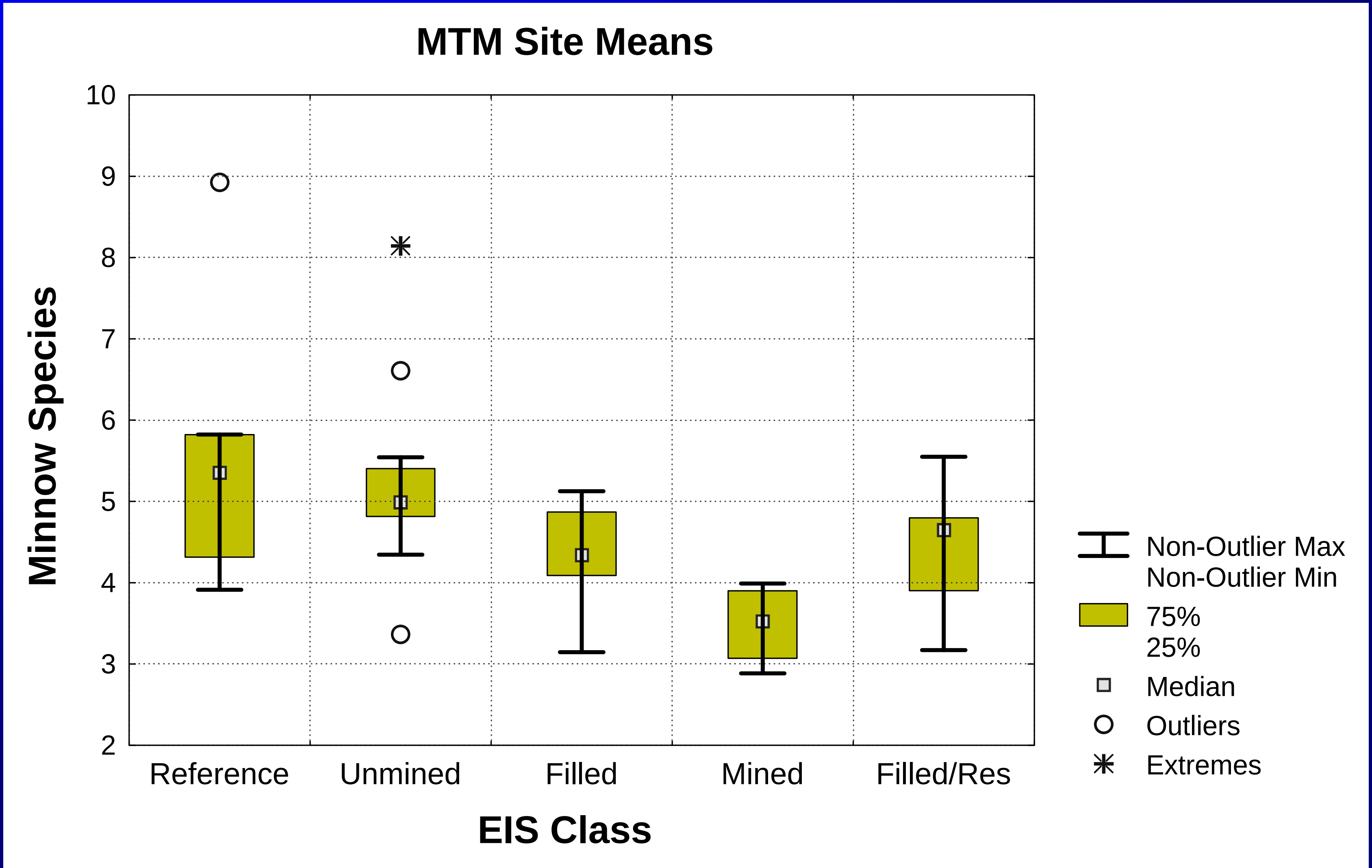
Mid-Atlanitc IBI: Filled vs. Unmined

Unmined sites have higher biotic integrity than filled sites



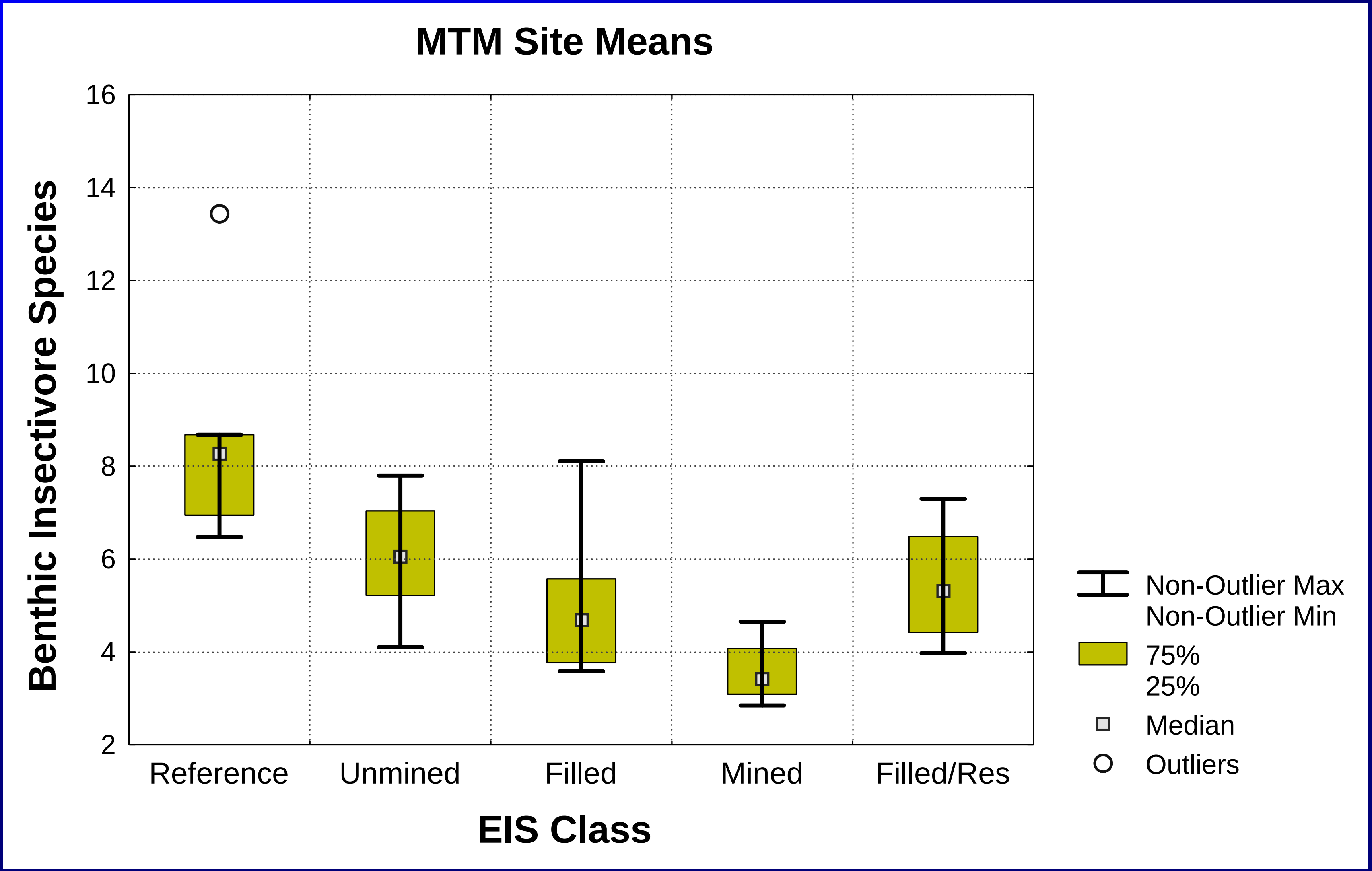
Minnow species: Filled vs. Unmined

Unmined sites have more minnow species than filled sites



Benthic Insectivore Species: Filled vs. Unmined

Unmined sites have more benthic insectivore species than filled sites



Fish Analysis Results: Comparison of EIS Classes

- Filled and Mined classes had lower IBI scores than Unmined
- IBI reduction in filled sites driven by loss of minnow species (Cyprinidae) and loss of benthic insectivore species
- IBI reduction not uniform: several Filled sites apparently unaffected
- *Filled/Residential the same or higher than Unmined*

Filled/Residential the same or higher than Unmined

- Subwatershed area may buffer/mitigate stressors
- Filled or Mined Sites < 10 km^2
  - IBI nearly always Fair to Poor
- Filled or Mined Sites > 20 km^2
  - IBI nearly always Good to Excellent
- Filled/Residential sites tend to have larger subwatershed areas

Fish Analysis Results: Additive Sites

- Two watersheds, Twelvepole Creek (mining + residential) and Twentymile Creek (mining only)
- No pattern in Twelvepole Creek; most observations in “Fair” range
- Twentymile Creek IBI in “Good” range to confluence of Peachorchard; in “Poor” range below Peachorchard

Water Quality Associations

- Small sites (<10 km^2)
- Zinc, sodium, and sulfate negatively correlated with IBI score; all may be leachate from mine spoil

rate Analysis Results

WVSCI Core Metrics

- Differentiate between reference and stressed samples
- Represent different aspects of the community (richness, composition, tolerance)

✓ Total Taxa
✓ EPT Taxa
✓ % EPT
✓ % Chironomidae
✓ % Top 2 Dominant Taxa
✓ Family HBI

Analysis of Macroinvertebrate Data

- Comparisons made for each of six seasons
- Only data from Twentymile Creek watershed available for last two seasons
- WV SCI and component metrics were primary analysis endpoints

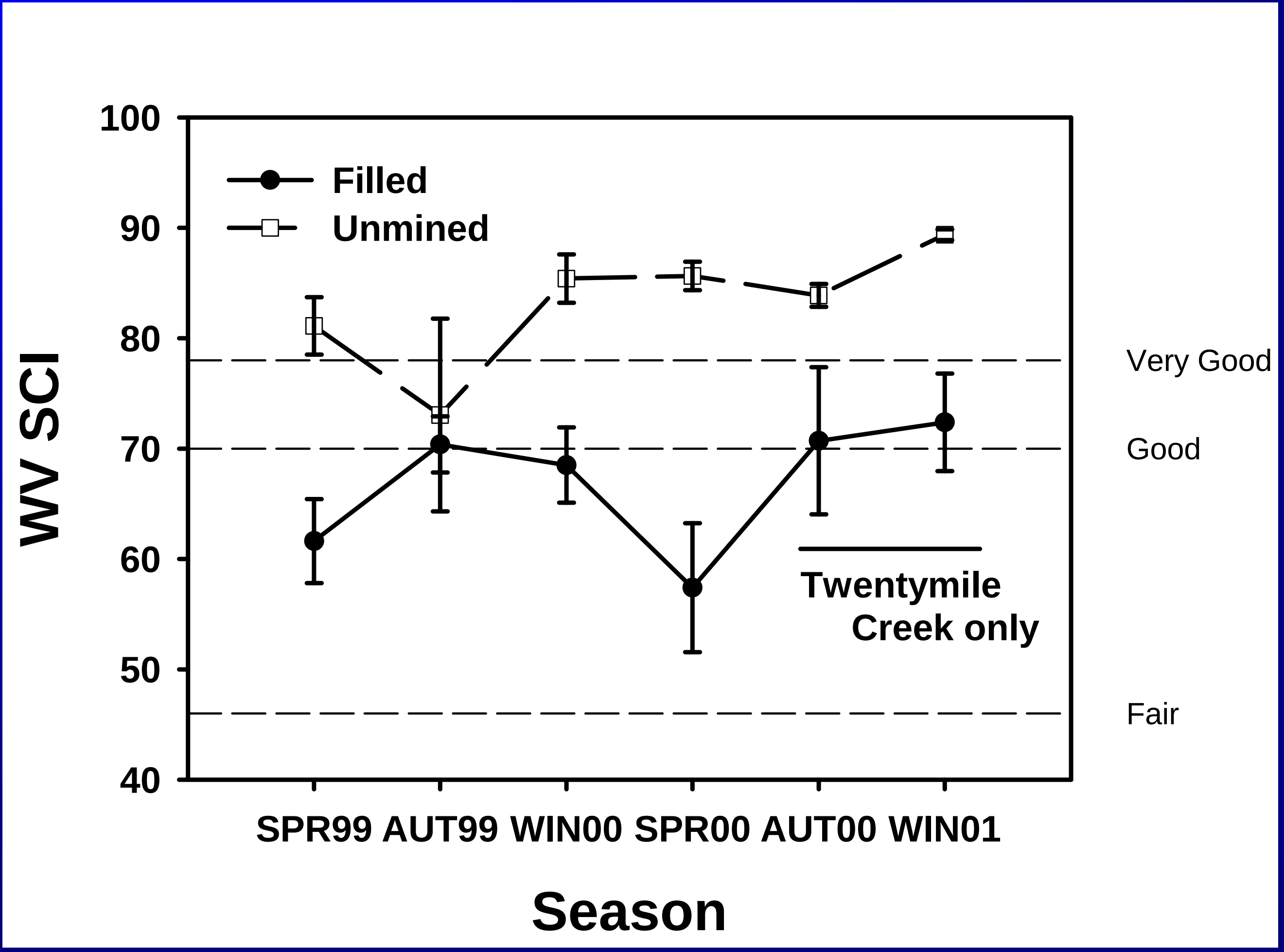
EIS Class Comparisons by Season: WV SCI

Season	P-value	Vs. Unmined Only
Spring 1999	<0.0001	Filled, Fill & Res.
Autumn 1999	0.0454	
Winter 2000	<0.0001	Filled, Fill & Res.
Spring 2000	0.0001	Filled, Fill & Res.
Autumn 2000*	0.1945	
Winter 2001*	0.0110	Filled

*Twentymile Creek only

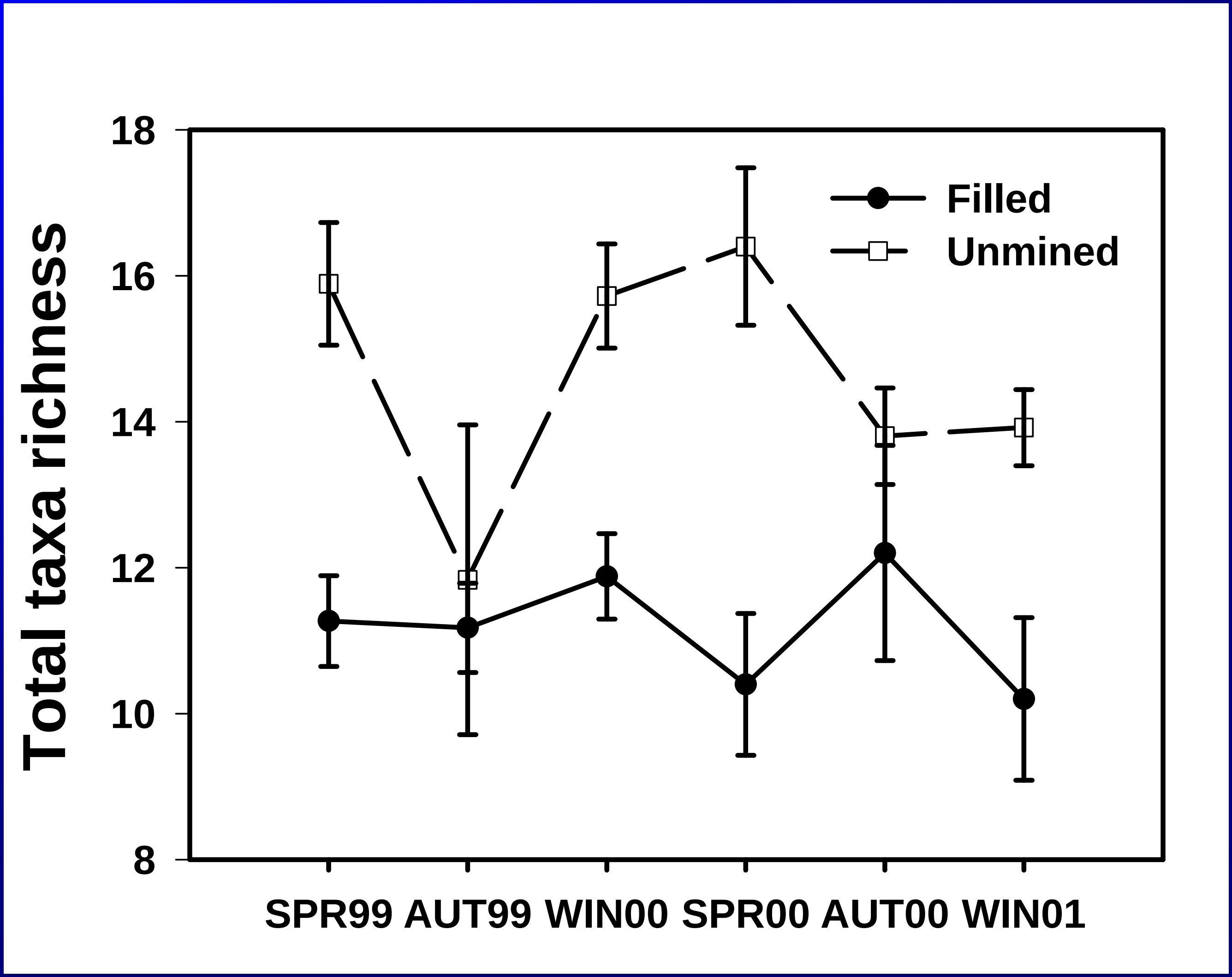
WV SCI: Filled vs. Unmined

Unmined sites have higher biotic integrity



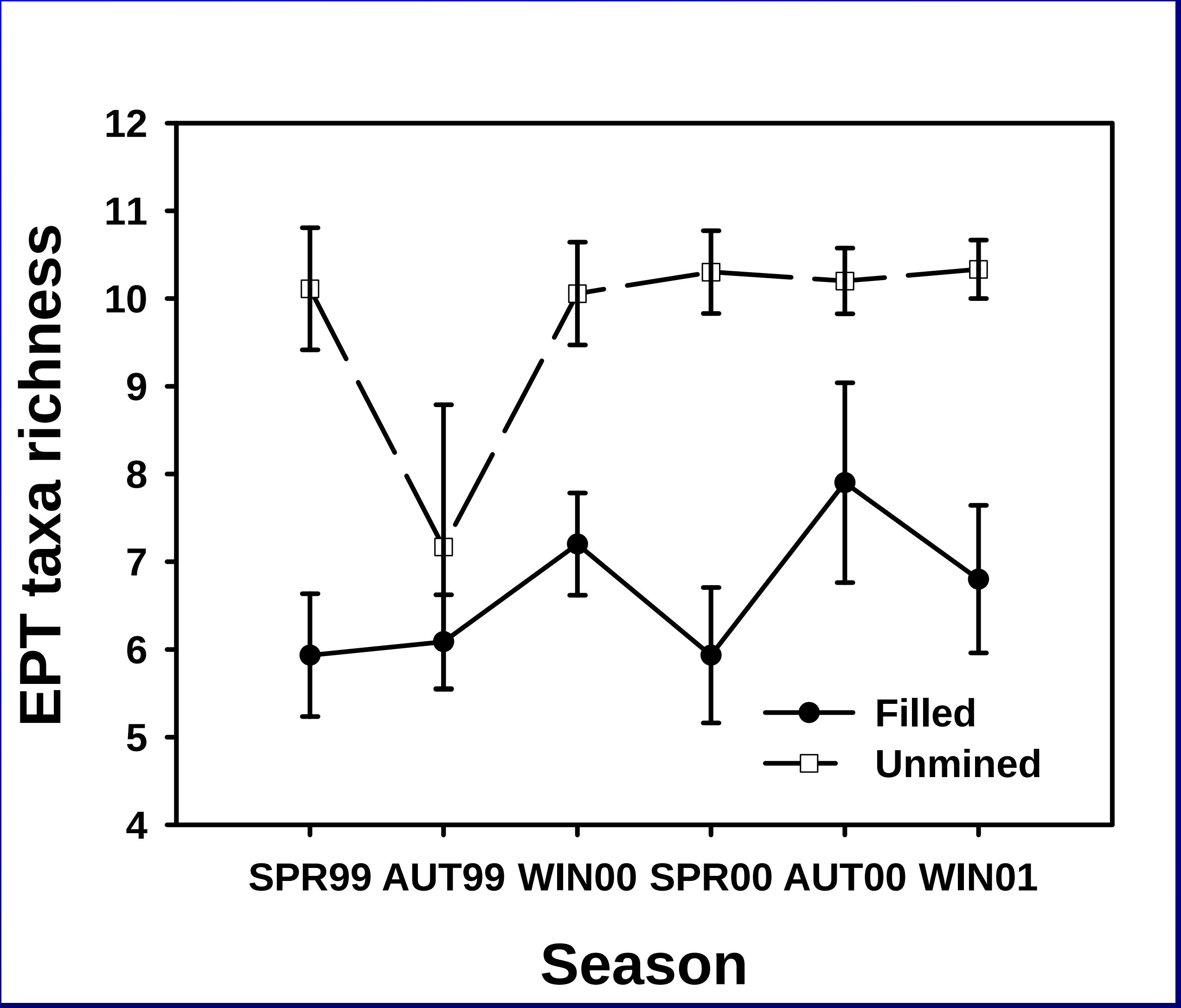
Total taxa richness: Filled vs. Unmined

Unmined sites have more taxa



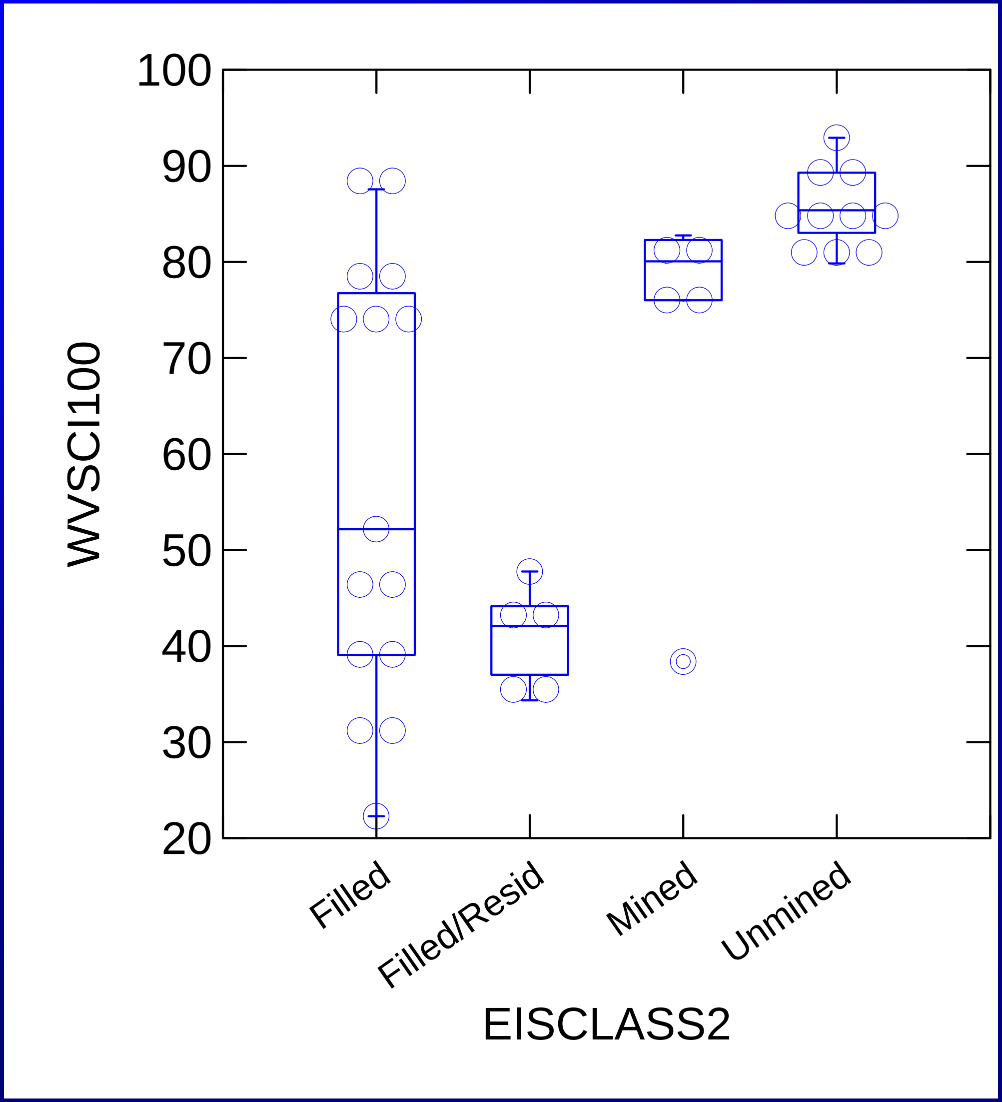
Sensitive taxa richness: Filled vs. Unmined

Unmined sites have more sensitive taxa



WV SCI Score Distribution by EIS Class

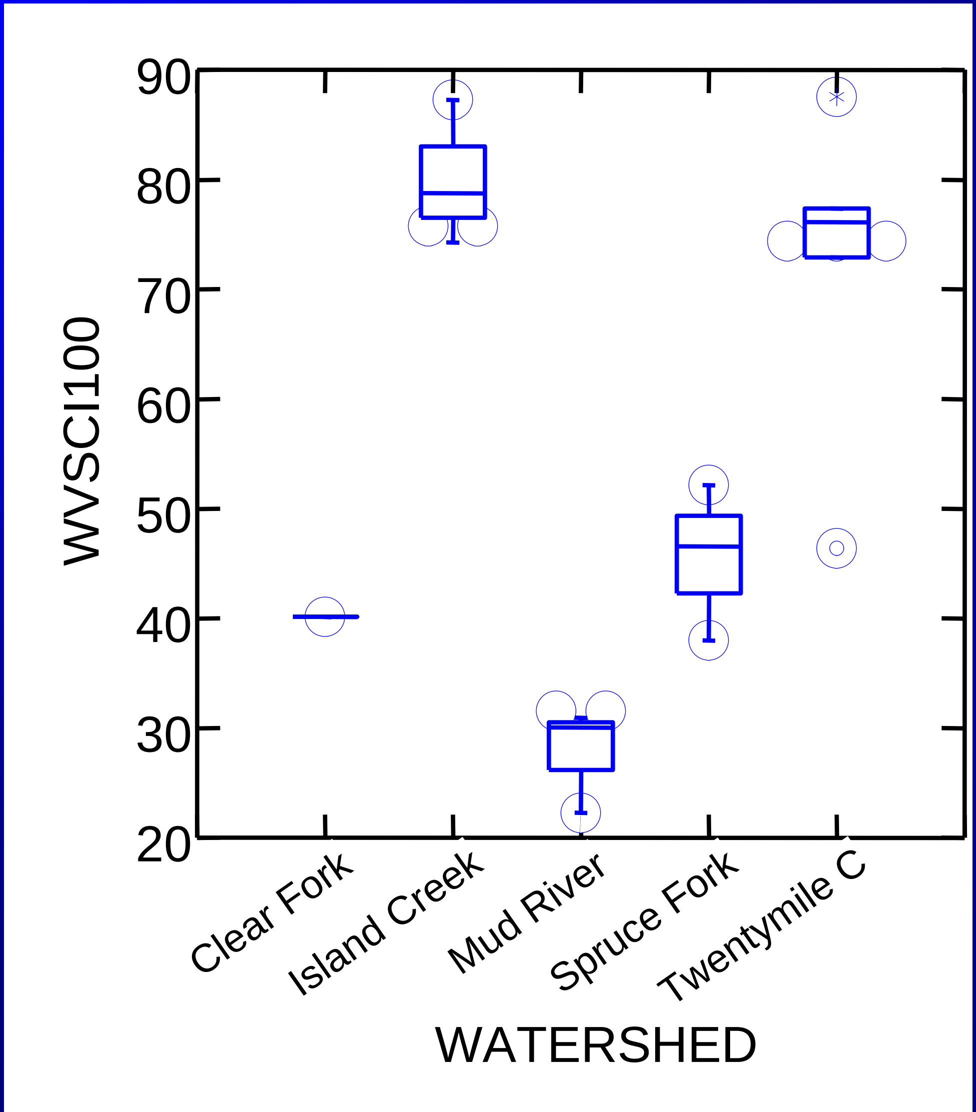
Note bi-modal distribution of Filled sites



Spring 2000

WV SCI Scores in Filled Sites

Bi-modality due to scores differing by watershed
Note the high scores in Twentymile Creek



Spring 2000

Macroinvertebrate Analysis Results: Comparison of EIS Classes

- Biological integrity based on macroinvertebrates is [illegible] sites than in Unmined sites
- Reduced biological integrity primarily a result of a loss of total and sensitive taxa in Filled sites
- Conditions in Filled sites varies by watershed
- Certain water quality parameters are negatively correlated with biological integrity

Macroinvertebrate Analysis Results: Additive Sites

- Examined sites along Twentymile Creek
- Samples collected Autumn 1999 to Winter 2001
- Impacts increased across seasons and upstream to downstream (17 km)
- Winter 2001: WV SCI decreased approximately 1 point for each stream km
- Space and time may be surrogates for increased mining activity in the watershed

Water Quality Associations

- Increased levels of ions are negatively correlated with the WV SCI
  - Conductivity
  - Total Dissolved Solids (TDS)
  - Ca, Mg, K, Na, Sulfate
- Increased levels of Se and Zn are negatively correlated with the WV SCI

Aquatic Impacts Study Conclusions

- Biological integrity is impacted downstream of mining activity with fills
- Strongest associations are with water chemistry parameters
  - Zinc, sodium and sulfate correlated with both fish and macroinvertebrates
- Potential drivers of condition:
  - Mining practices and material handling
  - Geological factors associated with coal seams, including overburden

Data Gaps

- Additional data for Mud River, Spruce Fork, and Clear Fork
- Before-after time series data for fill and unmined sites

Data Gaps (cont.)

- Information on mining practices:
  - Size and age of fills
  - Proportion of subwatershed that is mined - the relative amount of subwatershed that is mined is greater in smaller subwatersheds than in larger subwatersheds
  - Material handling
  - Geological information on coal beds & overburden

A SURVEY OF THE CONDITION OF STREAMS IN THE PRIMARY REGION OF MOUNTAINTOP MINING/VALLEY FILL COAL MINING

November 2000

Prepared For:

Mountaintop Mining/Valley Fill
Programmatic Environmental Impact Statement

Prepared by:

Jim Green
Maggie Passmore
USEPA Region 3
Wheeling, WV

and

Hope Childers
Signal Corporation
Wheeling, WV

US Environmental Protection Agency
Region III -, *Aquatic Biology Group*
303 Methodist Bldg, 11th & Chapline Sts.
Wheeling, WV 26003
Telephone: 304/234-0240
Telefax: 304/234-0260

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
CHIA	Cumulative Hydrologic Impacts Assessment
CPC	Climate Precipitation Center
EMAP	Environmental Monitoring and Assessment Program
EIS	Environmental Impact Statement
EPT	Ephemeroptera, Plecoptera, Trichoptera
HBI	Hilsenhoff Biotic Index
KYDW	Kentucky Division of Water
MDDNR	Maryland Department of Natural Resources
MTM/VF	Mountaintop Mining/Valley Fill
MTR/VF	Mountaintop Removal/Valley Fill
NDMC	National Drought Mitigation Center
NERL	National Exposure Research Laboratory
NWS	National Weather Service
OMR	Office of Mining Resources
ORD	Office of Research and Development
OSM	Office of Surface Mining
OWR	Office of Water Resources
PEIS	Programmatic Environmental Impact Statement
RBP	Rapid Bioassessment Protocol
RMSE	Root Mean Square Error

SCI	Stream Condition Index
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WVDEP	West Virginia Division of Environmental Protection

1.0 EXECUTIVE SUMMARY

A typical mountaintop mining/valley fill (MTM/VF) mining operation in the Appalachian coal fields removes overburden and interburden material to facilitate the extraction of coal. Excess spoils are often placed in adjacent valleys containing first and second order streams. The effect of these mining operations on the biological condition of reaches downstream of the fills is uncertain. This study was designed to provide information on the biological condition of streams downstream of a variety of MTM/VF activities.

This study considered three objectives:

1. Characterize and compare conditions in three classes of streams: 1) streams that are not mined (termed "unmined"); 2) streams in mined areas with valley fills (termed "filled"); and 3) streams in mined areas without valley fills (termed "mined").

2. Characterize conditions and describe any cumulative impacts that can be detected in streams downstream of multiple fills.

3. Characterize conditions in sediment control structures (ditches) on MTM/VF operations.

The original objectives describe three classes (unmined, filled and mined), but this final report discusses four classes (unmined, filled, filled/residential and mined). Preliminary analysis of the data indicated that streams with both valley fills and residences in their watersheds appeared to be more impaired than streams with only valley fills (no residences) in their watersheds. Since we were interested in characterizing the effects of valley fills on streams, we separated those sites with both valley fills and residences in their watersheds into a new category described as "filled/residential". There were six sites that had both valley fills and multiple residences or small communities in their watersheds. To be consistent, we also identified two sites in the mined class that had residences in their watersheds, described as "mined/residential". Since there were only two of these sites, they were not included as a separate group in analysis. There was one site in a sediment control structure that was not included in the analysis of classes since there was only one of these sites, and the site habitat was more typical of ponds and wetlands than natural streams.

In this study, we evaluated benthic macroinvertebrate assemblage data, physical stream habitat assessments, quantitative estimates of substrate size, and limited field chemical/physical parameters. Please contact the authors if you would like electronic files of the raw data.

1.1 Objective 1: Summary of Findings

Biological conditions at the unmined sites were comparable to a broad state-wide wadeable streams reference condition developed by the West Virginia Department of Environmental Protection (WVDEP). This reference condition was based on a data set of 1268 benthic samples collected from 1996 to 1998. This reference condition defines condition categories of very good,

good, fair, poor and very poor based on Stream Condition Index (SCI) scores. Scores in the fair, poor and very poor range are impaired relative to the reference condition.

Biological conditions at the unmined sites were also comparable to conditions in a smaller set of WVDEP reference sites (7 sites) which are located in the primary region of MTM/VF coal mining. These sites were sampled in 1997 and 1998 by the WVDEP.

Biological conditions in the unmined sites generally represented a gradient of conditions from good to very good, based on the WVDEP SCI scores. These sites are primarily forested, with no residences in the watersheds. One site scored in the high-end of the fair range in the summer of 1999, one site scored in the poor range in the fall of 1999, and one site scored in the high-end of the fair range in the winter of 2000. We believe these sites scored lower primarily because the drought and lower flows impeded our ability to collect a representative sample. We observed no other changes at these monitoring sites that could account for the changes in the condition of the streams, other than the low flows. When these sites were sampled in later index periods, they scored in the good or very good range.

Biological conditions in the mined sites generally represented very good conditions, although a few sites did score in the good and poor range. We believe that the one site that scored in the poor range is naturally flow-limited even during periods of normal flow. We believe this site is ephemeral and only flows in response to precipitation events and snow melt. The other mined sites generally have only a small amount of mining activity in their watersheds. In fact, many of these sites were believed to be in the unmined class prior to the first round of sampling and ground truthing.

Biological conditions in the filled sites generally represented a gradient of conditions from poor to very good. One site scored in the very poor range in the spring of 2000. Over the five seasons, filled sites scored in the fair range more than half of the time. However, over a third of the time, filled sites scored in the good or very good range over the five seasons. We believe water quality explains the wide gradient in biological condition at the filled sites. The filled sites that scored in the good and very good range had better water quality, as indicated by lower median conductivity at these sites. The filled sites that scored in the fair, poor and very poor ranges had degraded water quality, as indicated by elevated median conductivity at these sites (see figures 86 and 87).

Biological conditions in the filled/residential sites (filled sites that also have residences in their watersheds) represented a gradient of conditions from poor to fair. Over the five seasons, filled/residential sites scored in the poor range more than half of the time. The remainder of the filled/residential sites scored in the fair range. No sites in the filled/residential class scored in the good or very good range. All sites in the filled/residential class had elevated median conductivities.

In general, the filled and filled/residential classes had substantially higher median conductivity than the unmined and mined classes. It is important to note that the filled sites generally had comparable or higher conductivity than the filled/residential sites within a watershed, indicating that the probable cause of the increase in the total dissolved solids at the filled/residential sites was the mining activity upstream rather than the residences. Unfortunately, there are no aquatic life criteria for conductivity or total dissolved solids.

Biological conditions in the filled and filled/residential classes were substantially different from conditions in the unmined class and were impaired relative to conditions in the unmined class, based on the WV SCI scores.

The filled/residential class was the most impaired class. The causes of impairment in this class could include several stressors (e.g. the valley fills, the residences, roads). It is impossible to apportion the impairment in this class to specific causes with the available data.

The general patterns of stream biological condition presented in the previous paragraphs were clear in all three seasons that have complete data sets (spring 1999, winter 2000 and spring 2000). By complete, we mean that the unmined sites could be sampled.

An independent benthic data set collected at a subset of our sites in the winter 2000 season by Potesta and Associates, Inc. for Arch Coal supports our conclusions. Our analysis of the only complete data set provided by Potesta and Associates (Winter 2000) indicated that the sites in the filled and filled/residential classes were biologically impaired relative to the unmined sites (Green and Passmore 2000). The filled/residential class was the most impaired class.

Over the course of this study, pH, temperature and dissolved oxygen measurements were usually within the bounds of the aquatic life criteria for these parameters. (The only violation was measured in the sediment control structure). Acidity and low dissolved oxygen do not appear to be limiting the aquatic life in these streams. Temperature was fairly comparable within the four classes. Dissolved oxygen, pH and temperature can all vary during the day and through the seasons. The grab samples for these parameters may not be representative of long term water quality at these sites and should be treated with some caution.

It is not uncommon for streams to meet or exceed ambient water quality criteria but they do not fully support aquatic life. Biological communities respond to and integrate a wide variety of chemical, physical and biological factors and stressors. Ohio EPA (Yoder 1995) found that out of 645 waterbody segments analyzed, biological impairment was evident in 49.8% of the cases where no impairments of chemical water quality criteria were observed. In addition, as in this case, often only a few selected chemical parameters are measured, and they only offer a snap shot of the long term water quality in a stream..

The Rapid Bioassessment Protocols habitat assessment data did not indicate substantial differences between the stream classes. The habitat in the filled class and the filled/residential class was slightly degraded relative to the unmined class. Individual sites in the filled and filled/residential classes had degraded habitat and excessive sediment deposition.

In general, the substrate characteristics of the filled, filled/residential, and mined classes were not substantially different from the unmined class. Our data did not indicate excessive fines in the filled or the filled/residential classes as a whole, however, there were specific sites within these classes with substantially higher percentages of sand and fines compared to the unmined class. It should be noted that many of the filled sites were established in first and second order watersheds in order to limit the potential stressors in the watershed to the valley fills. Our data indicate that the valley fills and associated mining activity did not cause excessive sediment deposition in the upper reaches of these watersheds. It would not be appropriate to extrapolate our conclusions to reaches farther downstream in these watersheds or to larger order streams.

Correlations between the benthic metrics and selected physical and chemical variables indicate that the strongest and most significant associations were between biological condition and conductivity. Physical habitat variables were more weakly correlated with biological condition and some of these associations were not significant. Water quality appears to be the major factor limiting the benthos in the impaired streams.

Several unmined sites could not be sampled for benthos in the summer and fall of 1999 due to the drought. These sites were either dry or did not have adequate flow to collect a representative sample in these seasons. All of the unmined sites could be sampled by the winter 2000 sampling period and the conditions at most of the unmined sites scored in the good to very good range in the winter of 2000 (including the one unmined site that scored in the high-end of the fair range in the summer of 1999 and the one unmined site that scored in the poor range in the fall of 1999). One unmined site scored in the high-end of the fair range in the winter of 2000. All of the unmined sites scored in the very good range in the spring of 2000.

Most of the filled sites could be sampled for benthos in the summer and fall of 1999. We believe a probable cause for the sustained flows in the filled streams during the drought could be decreased evapotranspiration in those watersheds due to the replacement of forested cover with grassland cover on the mined areas. Decreased evapotranspiration has been found to increase streamflow (see section 2.3 for a more detailed discussion).

Our field observations and our data indicate that surface flow in the filled sites during the drought was greater than surface flow in the unmined streams. Some may conclude that this is a positive impact of mountaintop mining and valley fills, as this could result in perennial flow and hence benefit aquatic life. This position assumes two points: 1) the water quality in the filled streams does not change and 2) perennial flow is required for support of aquatic life. However, our data indicate that at many of the filled sites, the water quality was degraded due to the mining activity. So, even though there was more flow at the filled sites, the water quality was degraded. Furthermore, our data and the scientific literature indicate that benthic macroinvertebrates are clearly able to survive periods of low or no surface flow. In addition, some authors indicate that some benthic species are only found in intermittent flow regimes. Clearly, perennial flow regimes are not required to support diverse and abundant assemblages of macroinvertebrates (see section 5.1 for a more detailed discussion).

1.2 Objective 2: Summary of Findings

We used the WVDEP SCI scores to determine overall differences in biological condition upstream and downstream of four MTM/VF operations. A monitoring site was established as the upstream control, and a site was established as the downstream control. (We did not call these sites "reference" sites because in many cases, they were not comparable to reference conditions.) This was a difficult objective to explore. In three of the cases (Mud River, Spruce Fork, and Island Creek), there were potential stressors not related to the MTM/VF operations of interest located upstream of the upstream control site and in between the upstream and downstream control sites. The upstream control sites in the Mud River and in Spruce Fork were impaired and the upstream control site in Cow Creek (Island Creek) was not impaired. In one watershed (Clear Fork), this objective could not even be explored because several of the headwater streams in the watershed had been filled by the MTM/VF operation. The only substantial differences between the upstream and downstream sites were observed in Cow Creek (Island Creek). Biological conditions were much worse at the downstream site compared to the upstream site. The observed impairment could be caused by several stressors, including mining and residential land use.

1.3 Objective 3: Summary of Findings

We considered several sediment control structures as candidate monitoring sites. However, many of the sites were not reconstructed streams, but ponds or dry ditches filled with boulder-sized rip-rap. Only one sediment control structure was identified as having flowing water that could be sampled. Since only one such site was sampled, this study provides only limited information to characterize conditions in sediment control structures on MTM/VF operations.

Site MT24, located in a sediment control ditch on a surface mine, was more degraded than any site sampled in the study. The SCI score at this site was in the poor or very poor range over all five seasons. The entire drainage area of this site has been disturbed by mining. The ditch does not represent natural stream habitat. This was also the only site in the study where we observed a violation of a water quality criterion. In the summer 1999 index period, we measured a dissolved oxygen concentration of 3.6 mg/l, which is less than the required minimum of 5 mg/l.

2.0 INTRODUCTION

2.1 The Primary Region of Mountaintop Removal Coal Mining

The West Virginia Geological and Economic Survey has described the primary region of mountaintop removal coal mining in West Virginia (Fedorko and Blake 1998). They indicate that the majority of the mountaintop removal mines target the Coalburg coal zone and the overlying Stockton coal and associated riders (Kanawha Formation) and/or the "Block" coal zones of the overlying Allegheny Formation. The region encompassing the outcrop belt of these targeted zones includes portions of Lincoln, Wayne, Mingo, Logan, Boone, Wyoming, Raleigh, Kanawha, Fayette, Nicholas, Clay, Webster and Braxton counties.

The region lies in the Cumberland Mountains of the Central Appalachian Plateau (subecoregion 69d) (Woods et al 1999). Woods et al describe the physiography as being unglaciated, dissected hills and mountains with steep slopes and very narrow ridge tops. The geology is described as being Pennsylvania sandstone, siltstone, shale, and coal of the Pottsville Group and Allegheny Formation. The primary land use is forest with extensive coal mining, logging, and gas wells. Some livestock farms and scattered towns exist in the wider valleys. Most of the low-density residential land use is concentrated in the narrow valleys.

2.2 Monitoring Design and Rationale

This survey was designed to provide a synoptic description of stream conditions in five watersheds across the primary MTR/VF region, as defined by the West Virginia Geological and Economic Survey. These watersheds are Twentymile Creek of the Gauley River Basin, Island Creek and Mud River of the Guyandotte River Basin, and Clear Fork and Spruce Fork of the Coal River Basin (figures 1 and 2). Within each watershed, two arrays of streams were selected by staff familiar with the mining operations in the watershed (primarily WVDEP mining inspectors and the Streams Workgroup staff working on the PEIS). One stream array in each watershed was thought to be unmined. The other stream array in each watershed contained significant MTM/VF operations.

Since many characteristics of the candidate sites were largely unknown before the first field visit, it was impossible to correctly attribute sites prior to the first round of sampling. Some of the sites that were originally thought to be unmined had mining activity in their watersheds and were reclassified as mined. During field reconnaissance, it became apparent that the unmined sites were only in first and second order streams. There were no unmined sites in streams larger than second order. There was only a limited number of sites in the mined class, and the sites do not represent the full gradient of mined conditions. Many of the mined sites have only a small amount of historical mining activity in their watersheds.

The sites in the filled and filled/residential classes represent a gradient of number and size of fills, age of fills, and stream orders. We believe we have accurate data on the number of fills upstream of the sampling sites. However, the number of fills does not correlate to the total area of the watershed disturbed by mining or the area filled because of the wide variation in the size of the fills. We do not have accurate or detailed information on the size, age, or other characteristics of the fills. Therefore, we did not explore correlations between stream condition and fill characteristics (type, size, age, etc).

Preliminary analysis of the data indicated that the sites with valley fills and residences in their watersheds appeared to be more impaired than those sites with only valley fills in their watersheds. Therefore, in order to better characterize any impairment found in the filled class of sites, we created a new class of sites called filled/residential. Sites with valley fills and residences in their watersheds were put into this class.

Thirty-seven (37) benthic sampling sites were chosen from a larger pool of candidate sampling sites (a total of 127 sites) during the first sampling event in late April and early May of 1999. The thirty-seven (37) sites include nine (9) unmined sites, fifteen (15) sites with a valley fill or fills upstream of the sampling location, six (6) sites with both valley fills and residences upstream of the sampling location, and four (4) sites with some other sort of past mining activity upstream (other than valley fills) and no residences. In addition, two sites with past mining activity and residences in their watersheds and one site in a sediment control structure were chosen for monitoring. The nine unmined sites did not have any residences in the watershed upstream of the sampling site and were primarily forested. A list of the sampling sites and several attributes for the sampling sites are included in Appendix 1 (e.g. locational information, EIS class, stream order, watershed size).

In the spring of 2000, two more sites were added. One site was an unmined site which was added to provide a unmined reference site closer to the filled sites in the Island Creek watershed. The other site was located in the Mud River watershed and was added to provide another mined site to the small class of mined sites.

We considered several sediment control structures as candidate monitoring sites. However, many of the sites were not reconstructed streams, but ponds or dry ditches filled with boulder-sized rip-rap. Only one sediment control structure was identified as having flowing water and could be sampled. Since only one such site was sampled, this study provides only limited information to characterize conditions in sediment control structures on MTM/VF operations.

2.3 Effects of the Drought

The region of MTM/VF coal mining in West Virginia suffered periods of prolonged dryness and drought in 1998 and 1999. See Appendix 6 for a detailed discussion and documentation of the drought.

The drought clearly impacted our ability to effectively sample the streams. In the summer and fall of 1999 we could not collect representative invertebrate samples from several streams due to very low or no flows. Most of the flow-limited streams were unmined streams. Therefore, the summer and fall 1999 data sets are incomplete and provide limited data to determine the biological condition of the filled sites relative to unmined sites. For this report, we relied on the spring 1999, winter 2000 and spring 2000 datasets to draw conclusions about the biological conditions of streams and stream classes.

Our data indicate that when these streams could be effectively sampled, following the low flow conditions, they were in good or very good biological condition. Benthic invertebrates are clearly able to survive periods of low or no surface flow (see section 5.1 for a more detailed discussion).

Clearly, the drought and the decreased precipitation affected stream flow. Stream flow can also be affected by many characteristics of the watershed including porosity and permeability, infiltration, runoff, evapotranspiration, groundwater flow, etc (Farndon 1994). Mountaintop mining and valley fills alter many of these parameters. Evapotranspiration is the major use of water in all but extremely humid, cool climates. Furthermore, the majority of the water loss due to evapotranspiration takes place during the summer months. If evapotranspiration is reduced, then runoff or ground-water infiltration or both could increase. Studies have shown that basin runoff from a forested watershed increased following the timbering of a watershed. In some areas of the humid eastern United States, which were originally in forest, as old fields reconverted to forests, there was a concomitant decrease in streamflow. Conversion of one plant cover to another can also affect the evapotranspiration rate. In arid Arizona, the conversion of a plot of land formerly covered with chaparral to grasses resulted in streamflow increases of several hundred percent (Fetter 1988). Clearly, at the filled sites, the evapotranspiration rates in the watershed could be affected by the changes in vegetative cover (from forest lands to grasslands) associated with the mining activity.

2.4 Monitoring Parameters and Their Frequency of Collection

Streams were sampled in five seasons (spring 1999 (late April and early May), summer 1999 (late July and early August), fall 1999 (late October and early November), winter 2000 (late January and early February) and spring 2000 (late April and early May)) for a suite of biological, chemical/physical and physical habitat measures, when adequate flows allowed. Every parameter was not sampled each season (see below).

Several of the streams could not be sampled during the summer and fall 1999 sampling seasons, as the streams were either completely dry or the flow was too limited to allow benthic sampling. In this study we define “flow limited” streams as those streams with some flow, but with insufficient flow to effectively carry organisms and debris into the sampling net.

Monitoring parameters, sampling methods and their frequency of collection are described in depth in the Quality Assurance Project Plan for this study (Green et al 1999). These methods are summarized here. In the field, a study reach of 100 meters of longitudinal stream length was established for sampling sites with a mean wetted width of 2.5 meters or smaller. At some of the larger sites, it was necessary to sample a longer reach for the substrate size characterization protocol. At these sites, a reach length of forty times the wetted width was used, up to a maximum of 500 meters. A site identification section and sketch of each site was completed in the field once during the study period, unless conditions changed and then another sketch and description were completed to reflect those changes. Upstream and downstream photos of each sampling site were taken during each visit.

The benthic sampling site was located at the mid point of the reach unless the site-specific circumstances required that the reach be moved upstream or downstream to avoid tributary effects, bridges or fords. Macroinvertebrate were sampled using the USEPA Rapid Bioassessment Protocols (RBP) single habitat sampling protocol (Barbour et al 1999). The sample was collected in riffle habitat only. A 0.5 meter wide, 595 micron rectangular sampling net was used to collect organisms in a 0.25 square meter area upstream of the net. Four samples, each representing 0.25 square meters of riffle habitat, were composited. The total area sampled for each sample was approximately 1 square meter.

About 25% of the samples were sampled in replicate to provide an estimate of within season/within site variability. Replicates samples were collected at the same site, at the same time, and usually in adjacent locations within the same riffle. In some cases it was necessary to collect the replicate sample in an adjacent riffle. These replicates were highly correlated to each other (Appendix 5). Where replicates were collected, only the first sample collected was used when graphing the data and in descriptive and statistical analyses of the data.

The RBP single habitat protocol was slightly modified to collect 1 square meter of substrate rather than 2 square meters. This modification was made because many of the streams sampled were small. It would have been difficult to sample 2 square meters of riffle habitat in some of the streams in each of the four seasons. Because of the drought, we felt that a smaller sampling area would make it more likely that we could collect comparable samples over the five seasons.

We believe the 1 square meter sampling area provided sufficient sampling area to collect a representative sample. This finding is based on a comparison of our benthic data to the WVDEP reference condition. Samples collected by USEPA from unmined sites using the 1 square meter sampling area were of comparable condition to samples collected by WVDEP at reference sites in the MTM/VF region using the 2 square meter sampling area, based on the WVDEP Stream Condition Index (SCI) scores. The conditions of the unmined streams sampled in this study were characterized as good or very good using the WVDEP SCI. Conditions of very good are highly comparable to the WVDEP reference condition (above the 25th percentile) and conditions of good are comparable to the below average reference sites (between the 5th and 25th percentiles). Clearly, if the unmined sites we sampled using the 1 square meter technique scored in the same condition class as the WVDEP reference sites sampled using the 2 square meter sampling technique, we collected a representative sample of the benthic assemblage which was comparable to the WVDEP reference condition.

Samples were preserved in 100% ethanol. In the laboratory, a 1/8th subsample was picked and the organisms were identified using published taxonomic references (Merritt and Cummins 1996, Peckarsky et al 1990, Pennak 1989, Stewart and Stark 1993, Westfall and May 1996, Wiggins 1998) to the family level, except for Oligochaeta (worms) and leeches which were identified at the class level. This subsampling method is a standard level of effort approach. Every sample was picked a second time by an independent picker. Pick error rates were recorded for every sample. All picking and identification was done in the USEPA Wheeling, WV laboratory. Benthic macroinvertebrate samples were collected at each site, in each season, provided there was sufficient flow for sampling.

The stream physical habitat was assessed using USEPA RBP protocols (Barbour et al 1999). The RBP habitat protocol rates 10 aspects of physical habitat on a scale of 1 to 20 for an overall maximum possible rating of 200. Parameters evaluated in the sampling reach include epifaunal substrate/available cover; embeddedness; velocity/depth regimes; sediment deposition; channel flow status; channel alteration; frequency of riffles; bank stability; bank vegetative protection; and riparian vegetation zone width. The habitat assessment was performed on the reach that encompassed the biological sampling site. Some parameters do require an observation of a broader area of the catchment other than the sampling reach.

Physical habitat evaluations were performed at all sites which were sampled for benthic macroinvertebrate in the fall of 1999. However, the flow at several of the sites was very low and these sites could not be sampled for benthos in the fall of 1999. Physical habitat evaluations were completed for these sites in the spring of 2000, when adequate flow was present to sample the benthic assemblage. The physical habitat evaluations performed at flowing sites in the fall of 1999 were reviewed in the field in the spring of 2000. Any changes from the fall of 1999 to the spring of 2000 were noted on the original sheet. For example, channel flow status and velocity depth regimes vary with flow, and many of these parameter scores changed from the fall of 1999 to the spring of 2000. Only the spring 2000 habitat assessments were used in this report to determine habitat condition.

Dissolved oxygen, conductivity, temperature, and pH were measured in situ using a Corning Check Mate Field Meter. The field chemical/physical measurements were taken directly upstream of the biological sampling site, prior to benthic sampling. The field chemical/physical parameters were generally measured at all sites with sufficient flow in each season, except for dissolved oxygen. Dissolved oxygen was not measured at all sites in the spring of 1999 due to meter malfunction.

Substrate size characterizations were measured using USEPA Environmental Monitoring and Assessment Program (EMAP) protocols (Lazorchak et al 1998, and Kaufmann et al 1999). This method was slightly modified from the original in that 100 meters were used for the study reach at all streams with an average wetted width of 2.5 meters or smaller. At some of the larger sampling sites, forty times the wetted width was sampled, up to a maximum of 500 meters. Starting at zero meters, eleven transects at equal intervals were measured over the sampling reach. These transects were defined by the wetted width. Five measurements were taken at evenly spaced intervals across each transect (left, left middle, middle, right middle, and right). Substrate particles in the transects were assigned to substrate classes. Five particles were randomly selected, measured and assigned a substrate size class in each of the 11 transects, for a total of 55 particle measurements. The 55 measurements and resulting size classes were used to estimate the proportion of bedrock, boulder, cobble, coarse gravel, fine gravel, and sand and fines present in the reach and the mean particle size in the reach. Bankfull height, thalweg depth, slope, and wetted width were also recorded for the reach. Thalweg depth and wetted width were recorded for each transect. Average bankfull height and overall slope were calculated for the reach.

The substrate size characterizations were measured twice during the study period at selected sites. Measurements were taken at all sites sampled for benthic macroinvertebrate in the fall of 1999. However, the low flow prevented sampling of several sites. Thus, the substrate measurements were repeated at all sites in the spring of 2000, to provide complete data for all sites. Only the spring 2000 substrate size measurements were used to characterize substrate conditions.

Land cover information for the subwatersheds upstream of the sampled sites was considered for use in this report. However, after extensive review of the land cover data set, ground-truthing, and input from our peer reviewers, we decided the information did not accurately represent the land cover in the subwatersheds at the time the biological and chemical data were collected. The percent land cover classified as Quarries/Mining appeared to underestimate the actual area surface mined because surface mining has continued since 1993 (the Landsat images were made in 1993). Furthermore, older surface mines were classified as grasses or forest cover if they were covered with vegetation when the 1993 Landsat images were made. Similarly, residential land cover did not seem to be properly characterized by the Landsat images. We believe this is due both to the age of the land cover, and the small size of the residential tracts in this region of southern West Virginia. Many of the residential units are single trailers in very narrow strips along the streams.

3.0 WATERSHED DESCRIPTIONS

Detailed descriptions of the sampling sites and a table of several attributes for the sampling sites are included in Appendix 1 (e.g. locational information, EIS class, stream order, watershed size).

3.1 Mud River Watershed

The headwaters of the Mud River rise in Boone County and flow in a northwesterly direction into Lincoln County. Most of the watershed lies in Lincoln County. The headwaters of the Mud River watershed do not lie in the primary mountaintop mining area as described by the West Virginia Geological and Economic Survey (figure 1). In this watershed, the area of concern is a strip of land approximately five miles wide that runs perpendicular to the watershed and straddles the Boone and Lincoln County line. The remaining downstream watershed is out of the area of concern.

From the headwaters to the northwestern boundary of the primary mountaintop mining area, the watershed lies in the Cumberland Mountains of the Central Appalachian Plateau (subecoregion 69d) (Woods et al 1999) (figure 2). Woods et al describe the physiography as being unglaciated, dissected hills and mountains with steep slopes and very narrow ridge tops. The geology is described as being Pennsylvania sandstone, siltstone, shale, and coal of the Pottsville Group and Allegheny Formation. The primary land use is forest with extensive coal mining, logging, and gas wells. Some livestock farms and scattered towns exist in the wider valleys. Most of the low-density residential land use is concentrated in the narrow valleys.

The remainder of the watershed lies in the Monongahela Transition Zone of the Western Allegheny Plateau (subecoregion 70b). The Monongahela Transition Zone is outside the primary area of mountaintop mining. However it is mined and there are fills associated with this mining. This area is unglaciated with more rounded hills, knobs, and ridges compared to the dissected hills and mountains with steep slopes and very narrow ridge tops found in the Central Appalachian Plateau (Woods et al 1999). Land slips do occur in the Monongahela Transition Zone. The geology is Permian and Pennsylvanian interbedded sandstone, shale, limestone and coal of the Monongahela Group and less typically the Waynesboro Formation. The primary land use is forest with some urban, suburban, and industrial activity in the valleys. There is also coal mining and general farming in this region.

3.2 Spruce Fork Watershed

The Spruce Fork watershed drains portions of Boone and Logan Counties. The stream flows in a northerly direction to the town of Madison where it joins Pond Fork to form the Little Coal River. About 85 to 90 percent of the watershed resides in the primary mountaintop mining region (figure 1). Only the northwest corner lies outside this region. The entire watershed lies within subecoregion 69d (Cumberland Mountains) (figure 2). The watershed has been the location of surface and underground mining activity for many years, and numerous subwatersheds have been disturbed.

3.3 Clear Fork Watershed

Clear Fork flows in a northwesterly direction to its confluence with Marsh Fork where they form the Big Coal River near Whitesville. The entire watershed lies within Raleigh County. All but a tiny part of the watershed is within the primary mountaintop mining area and is within subecoregion 69d (Cumberland Mountains) (figures 1 and 2). The coal mining industry has been active in this watershed for many years. Both surface and underground mining have occurred in the past and continue today. Two subwatersheds, Sycamore Creek and Toney Fork, were sampled as part of this survey.

3.4 Twentymile Creek Watershed

Twentymile Creek drains portions of four counties: Clay, Fayette, Kanawha, and Nicholas. It flows generally to the southwest where it joins the Gauley River at Belva, West Virginia. Except for a small area on the western edge of the watershed, it is within the primary mountaintop mining area, and it all lies within subecoregion 69d (Cumberland Mountains) (figures 1 and 2). The watershed upstream of Vaughn is uninhabited. Logging, mining, and gas wells are the primary activities upstream of Vaughn. There has been a limited amount of old mining in the watershed above Vaughn but the majority of the mining activity is more recent. Downstream of Vaughn there are numerous residences and some small communities.

3.5 Island Creek Watershed

Island Creek flows in a generally northerly direction to Logan where it enters the Guyandotte River. The entire watershed is confined to Logan County. All but the northern part of the watershed lies in the primary mountaintop mining area and the entire watershed is located in subecoregion 69d (Cumberland Mountains) (figures 1 and 2). Extensive underground mining has occurred in the watershed for many years. As these reserves have been depleted and economics have changed, surface mining has taken on a bigger role in the watershed.

4.0 DATA ANALYSIS METHODS

4.1 Multi-Metric Stream Condition Index

Several individual metrics and a multi-metric index were used to evaluate the benthic macroinvertebrate data. A multi-metric index known as the Stream Condition Index (SCI) was developed by Tetra Tech, Inc. using WVDEP benthic data for West Virginia wadeable streams (Gerritsen et al 2000). This index was developed to detect impact from a broad range of stressors, not solely for mining related impacts. The SCI was developed from a data set of 1268 benthic samples (including 107 reference samples) collected in riffle habitats from 1996 to 1998. The SCI was originally developed using data collected from 1996 to 1997 and was later validated using an independent dataset collected in 1998. The SCI was developed in accordance with EPA guidance (Barbour et al 1999).

Six metrics make up the SCI: Total Taxa, Ephemeroptera Plecoptera Trichoptera (EPT) Taxa, % EPT, % Chironomidae, % Two Dominant Taxa, and a family-level Hilsenhoff Biotic Index (HBI). We relied heavily on the multimetric SCI as an overall indicator of stream condition and to report stream condition classes of very good, good, fair, poor and very poor. The individual metric values that make up the SCI were also used to analyze differences between the classes.

The six metrics were aggregated into an index by calculating the 5th percentile (% Chironomidae, % Two Dominant Taxa, HBI) or 95th percentile (% EPT, Total Taxa, EPT Taxa) for all 720 sampling sites in the WVDEP 1996-1998 database. These values were considered the standard, "best" values. These values were then assigned a score of 100. Values of a metric between the minimum possible value (or in some cases the maximum possible value) and the standard best score were then scored proportionally from 0 ("worst") to 100 ("best"). By standardizing the metric values to a common 100-point scale, each of the metrics contributes to the combined index with equal weighting, and all of the metric scores represent increasingly "better" site conditions as scores increase toward 100. Once all metric values for sites were converted to scores on the 100-point scale, a single multi-metric index value was calculated by simply averaging the individual metric scores for the site.

Thresholds for the index were developed using the SCI scores of the 107 reference samples. Index scores that exceed the 25th percentile of the reference site scores (>78) are considered to be highly comparable to the WVDEP reference sites and in very good condition. Index scores that are greater than the 5th percentile(>70) up to the 25th percentile of the reference site scores (78) are considered to be comparable to the below-average WVDEP reference sites and in good condition. Scores equal to or less than the 5th percentile of the reference site scores (70) are considered to be increasingly different from the WVDEP reference condition and impaired. Scores greater than 46 and up to 70 indicate fair conditions, scores greater than 23 and up to 46 indicate poor conditions, and scores between 0 to 23 indicate very poor conditions (Gerritsen et al 2000).

Richness metrics have been shown to be positively correlated with abundance (Gerritsen et al

2000). The target minimum sample size for this study was 100 individuals. For this project, the WVDEP samples were rarefied from their original target count of 200 organisms to 100 individuals to recalculate the standard best values for total taxa richness and EPT taxa richness. We then rarified our data to 100 organisms as well in order to score our samples using the rarefied SCI best standard values. Rarefaction is a statistical procedure which lets you directly compare the number of taxa found in samples when the sampling effort differed. Rarefaction uses the data from the original sample to answer the questions “how many taxa would have been found in a smaller sample?”. Rarefaction takes hypothetical subsamples of 100 organisms from the original sample, and calculates the richness metrics for each hypothetical subsample (Krebs 1998). Our rarefaction procedure took 100 hypothetical subsamples of 100 organisms from the original sample, and calculated an average taxa richness and EPT richness metric values for those 100 subsamples.

The scores for the WVDEP reference sites were recalculated using the rarefied SCI and the 5th and 25th percentiles were determined to establish the scoring ranges. The rarefied SCI is a slight modification to the original WV SCI. This modification was made to avoid a possible bias in the richness metrics by scoring samples with more organisms higher than samples with fewer organisms, possibly simply because there are more organisms (and hence more taxa) in one sample. These modifications did not make a difference in the final conclusions of this report.

4.2 Expectations for Individual Metric Values

General expectations for metric values in healthy streams were based on several years of assessment experience and the ranges of values found in the independent dataset of WVDEP reference sites used to develop the SCI.

The metric Total Taxa richness measures the number of families in the sample. Total Taxa richness generally decreases with increasing stream degradation. We generally expect healthy streams to have at least 20 taxa at the family level.

The metric EPT Taxa measures taxa richness in three insect orders known to be generally sensitive to disturbance (Ephemeroptera, Plecoptera, Trichoptera or mayflies, stoneflies and caddisflies, respectively). EPT Taxa generally decreases with degrading stream condition. Healthy streams in West Virginia commonly have 9 to 12 EPT taxa at the family level (Gerritsen et al 2000). This is a widely used index and is very sensitive to changes in water quality. One study found that the EPT index was sensitive to chemical-induced disturbances, but was relatively insensitive to natural disturbances, such as extreme discharges in small headwater streams (Wallace et al 1996). This same study found that the EPT index showed a “remarkable ability to track secondary production of invertebrates”.

The metric % EPT is based on the proportion of individuals in the sample that belong to the EPT orders. We generally expect that in healthy streams, a high percentage of the total organisms present should belong to the EPT orders. It is common in healthy streams that at least 70 to 90% of the total organisms are in these sensitive orders.

The metric % Chironomidae is based on the proportion of individuals in the sample that belong to the family Chironomidae. This metric generally increases with degrading stream condition. Since Chironomidae are very small organisms, the mesh size of the collecting net can affect the number of midges collected. This study and the WVDEP monitoring program used nets with 595 micron mesh size. Studies using smaller mesh sizes may result in higher numbers and relative abundance of Chironomidae. Based on the WVDEP dataset, and our experience using the 595 micron mesh net, it is not uncommon in healthy streams that less than 20% of the organisms in the sample belong to the family Chironomidae.

The Hilsenhoff Biotic Index (HBI) weights each taxon in a sample by its proportion of individuals and the taxon's tolerance value. Tolerance values are assigned to each family on a scale of 0 to 10, with 0 identifying the least tolerant (most sensitive) organisms, and 10 identifying the most tolerant (least sensitive) organisms. The HBI metric can be thought of as an average organic pollution tolerance value for the sample, weighted by the abundance of organisms. This metric increases with degrading stream conditions, especially where organic enrichment is present. Since some of the organic-tolerant organisms are also tolerant to other stressors, the HBI is often used as a general indication of stress. It is not uncommon for healthy streams with good water quality to have family-level HBI values in the range of 3 to 4.

The metric % Two Dominant Taxa is based on the proportion of individuals in the sample that belong to the two most dominant taxa. In healthy streams, there are generally several families, with the individuals evenly distributed among the different families. As stream degradation occurs, more individuals are concentrated in fewer, more tolerant families, and this metric generally increases. It is not uncommon for healthy streams to have as few as 40-60% of the total individuals in a sample in the 2 dominant taxa.

In addition to the individual metrics that make up the SCI, we also used the metrics Mayfly Taxa and % Mayfly to evaluate the data. Preliminary analysis of the spring 1999 benthic assemblage data indicated that mayfly populations were impaired in the filled streams. These metrics have been widely tested and found useful in numerous studies and are suggested for use in the EPA Rapid Bioassessment Protocols and related guidance (Barbour et al 1999).

The metric Mayfly Taxa enumerates the number of families of mayflies. Mayflies are generally sensitive organisms, and in healthy streams, it is not uncommon to find at least 3 or 4 families of mayflies. The metric % Mayfly is based on the proportion of individuals in the sample that are mayflies. Since mayflies are generally sensitive organisms, this metric decreases with increasing degradation. It is not uncommon for healthy streams to have as many as 20-40% of the total individuals in the sample be mayflies. As streams are degraded, the sensitive mayflies may be replaced with less sensitive taxa. Both metrics (Mayfly Taxa and % Mayfly) have been used in other multimetric indices and have been found to discriminate between reference and impaired sites (Voshell and Smith 1997, Stribling et al 1998, Barbour et al 1999).

4.3 Grouped Sites Analysis

Sites were grouped over the entire region by the four classes: unmined (no mining activity or residences upstream of the sampled site), filled (valley fill or fills upstream of sampling site but no residences), filled/residential (valley fill or fills upstream of sampling site and residences), and mined (some type of past mining activity upstream of sampling site, but no valley fills and no residences). The unmined class was used as the control class. We analyzed each season separately to minimize the effects of seasonal variability.

We calculated the mean and standard deviation of the metric scores for each class in each season. We compared the means of the four classes in each season. We also calculated the percentage of total sites in each SCI condition class (very good, good, fair, poor, very poor) by season and over all five seasons. We used box and whisker plots to compare the interquartile ranges (25th percentile to 75th percentile) of the metric values of the classes to the unmined control class.

In the box and whisker plots, we also compared our data to the subset of seven WVDEP reference sites that are located in the MTM/VF region. Three of these sites are located in the Elk Watershed (Camp Creek, Ike Fork, and Johnson Branch). Three of the sites are located in the Gauley Watershed (Bearpen Fork, Ash Fork, and Neil Branch). One site is located in the Lower Guyandotte Watershed (Laurel Creek). Six of the seven WVDEP reference sites are different locations from our unmined sites and provide another, independent point of reference for comparison. Six of the these WVDEP reference sites were sampled in July of 1997 and 1998 and one of these sites was sampled in May 1998. Although the WVDEP reference sites are not strictly comparable to our sites in seasons outside of the summer, they are provided as an optional point of reference in the box and whisker plots.

The two sites that were classified as mined but also had residences in their watersheds were not used in the analysis of the classes because there were so few sites in that class (MT01 and MT69). The site in the sediment control structure (MT24) was also not included in the analysis of the classes since it is the only site of this type and does not represent a natural stream habitat.

Several of the unmined streams could not be sampled during the summer and fall of 1999 due to the drought. We relied on the complete data sets collected in the spring 1999, winter 2000, and spring 2000 seasons to characterize condition in the streams using the unmined class as the control class. Descriptive statistics and graphs for the summer and fall 1999 seasons are included in the report for completeness.

Box-and-whisker plots and vertical point plots were used to evaluate differences in the interquartile ranges of metric values among the four classes. The box and whisker plots display descriptive statistics (median, mean, 25th percentile, 75th percentile, 10th percentile, 90th percentile, and outliers) of a population of sites. The box displays the upper quartile (75th percentile) and the lower quartile (25th percentile). The whiskers display the 90th percentile and the 10th percentile. The solid line in the box is the median. The dotted line in the box is the mean. Box and whisker plots are displayed for only those classes with at least 4 data points. Vertical point plots display all of the data points as an overlay on the box plot. For those classes and seasons where fewer than 4 sites were sampled, only the vertical point plot is shown on the graph.

The degree of overlap of the metric ranges in the four classes (i.e., unmined, filled, filled/residential and mined) was used to visually determine the degree of difference between the populations. No overlap of the interquartile ranges of metric values for the populations indicates the greatest degree of difference between the classes. Some overlap of the interquartile ranges, but the medians of the populations are outside of the interquartile overlap, indicates the next greatest degree of difference between classes. Moderate overlap of the interquartile ranges, but at least one median outside the interquartile range overlap indicates some difference between the classes. Extensive overlap of interquartile ranges and both medians within the overlap indicates little or no difference between the classes (Barbour et al 1996).

5.0 BIOLOGICAL CONDITION OF STREAMS

To assess the overall ecological condition of streams in the primary region of mountaintop coal mining, we relied on direct measures of the benthic communities that inhabit the streams. Biological communities reflect overall ecological integrity (i.e. chemical, physical and biological integrity). Therefore, biosurvey results directly assess the status of a waterbody relative to the primary goal of the Clean Water Act. The aquatic insects and other benthic organisms integrate the effects of all stressors to which they are exposed including water quality, degradation of physical habitat, and flow, and thus provide a broad measure of their aggregate adverse effect. These organisms also integrate stressors over time since many of them live in the water for periods of a year or more. Therefore, they provide an ecological measure of fluctuating conditions, rather than a snapshot like grab water quality measurements. Finally, where criteria for specific ambient impairments do not exist (i.e. effects that degrade habitat), biological communities are often the only practical means of evaluating the condition of streams (Barbour et al 1999).

5.1 Benthic Data: Summary of Findings

The West Virginia Stream Condition Index scores are summarized in tables 1 and 2. The percentage of sites in each condition class (very good, good, fair, poor and very poor) are presented by season and then by stream class in table 1. This table allows a quick analysis of how the site classes compared to each other within a season. The percentage of sites in each condition class are presented by stream class and then by season in table 2. This table allows a quick analysis of how the conditions of each site class changed from season to season.

In the seasons with complete data sets (spring 1999, winter 2000, and spring 2000), the unmined sites generally scored in the good to very good range using the WVDEP Stream Condition Index. Over all five seasons, the unmined sites scored in the very good range 72% of the time and in the good range 19% of the time (table 2). It is important to note that although many of the unmined sites could not be sampled in the fall and summer of 1999 due to the severe drought and low flows, once they could be sampled effectively, these sites scored in the good to very good range.

In contrast to the unmined sites, the filled sites scored over the entire range of conditions. Over all five seasons, the filled sites scored in the very good range 14% of the time, in the good range 19% of the time, in the fair range 53% of the time, in the poor range 12% of the time, and in the very poor range only 1% of the time. We believe the range of biological conditions found in the filled sites can be explained by differences in water quality (see section 7.0 for a discussion of the associations between biological condition and conductivity).

The filled/residential class showed even more impairment. Over all five seasons, sites scored in the fair range 43% of the time, and in the poor range 57% of the time. None of the sites in this class ever scored in the good or very good range.

Table 1. Summary of Stream Conditions Based on the WV Stream Condition Index Percentage of Sites in Each Condition Category by Season					
Stream Class (n)	**Very Good (>78-100)**	**Good (>70-78)**	**Fair (>46-70)**	**Poor (>23-46)**	**Very Poor (0-23)**
Spring 1999					
Unmined (9)	67	33	0	0	0
Filled (15)	27	7	53	13	0
Filled/residential (6)	0	0	17	83	0
Mined (4)	75	0	0	25	0
Summer 1999*					
Unmined (2)	0	50	50	0	0
Filled (15)	0	0	100	0	0
Filled/residential (6)	0	0	67	33	0
Mined (2)	50	50	0	0	0
Fall 1999*					
Unmined (2)	0	50	0	50	0
Filled (14)	7	43	50	0	0
Filled/residential (6)	0	0	83	17	0
Mined (1)	100	0	0	0	0
Winter 2000					
Unmined (9)	78	11	11	0	0
Filled (14)	21	14	50	14	0
Filled/residential (6)	0	0	33	67	0
Mined (3)	100	0	0	0	0
Spring 2000					
Unmined (10)	100	0	0	0	0
Filled (15)	13	33	13	33	7
Filled/residential (6)	0	0	17	83	0
Mined (5)	60	20	0	20	0

* A number of streams lacked sufficient flow to sample during the severe drought. For more detail on the drought and its effect on sampling, see section 2.3 and Appendix 6.

Very few mined sites were sampled. Over all five seasons, these sites scored in the very good range 73% of the time, in the good range 13% of the time, and in the poor range 13% of the time. The samples that scored in the poor range were collected at the same site, MT78. We believe this site is naturally flow limited for most of the year, not only during periods of drought. The other mined sites have limited amounts of mining activity in their watersheds. Many of these sites were thought to be unmined prior to the first round of field sampling and ground-truthing.

Over all three seasons with complete data sets (spring 1999, winter 2000 and spring 2000), the same pattern was evident: unmined sites scored generally in the good to very good range; the filled class described a wide range of conditions and over half of the filled sites were impaired relative to the unmined class; and the filled/residential class scored in the fair to poor range and all filled/residential sites were impaired relative to the unmined class.

Our data illustrate the ability of the benthic assemblages in the unmined streams to withstand natural periods of drought. Other studies have also concluded that intermittent streams are clearly capable of supporting diverse and abundant invertebrate assemblages:

For example, in Western Oregon taxa richness of invertebrates (>125 species) in temporary forest streams exceeded that in a permanent headwater stream (100 species) (Dietrich and Anderson 2000). Dietrich and Anderson also found that only 8% of the species in the total collection were only found in the permanent headwater. 25% were restricted to the summer-dry streams and 67% were in both permanent and summer-dry streams. In other words, most of the aquatic life found in the temporary streams were also found in permanent streams, clearly indicating that the temporary streams support aquatic life similar to that found in permanent streams. These researchers concluded that the potential of summer-dry streams with respect to habitat function is still widely underestimated.

In northern Alabama, Feminella (1996) quantified the flow in six similar-sized streams and compared benthic macroinvertebrate communities in those same six upland streams of varying hydrologic permanence . Two of the streams were normally intermittent, three occasionally intermittent, and one rarely intermittent. Despite the differences in flow, the invertebrate assemblages differed only slightly. Presence-absence data revealed that 75% of the species were found in all six streams or showed no pattern with respect to flow permanence. Seven percent (7%) of the total species were found exclusively in the normally intermittent streams. In other words, the benthic assemblage can withstand periods of dryness, probably by burrowing into the wet subsurface zones or taking refuge in residual pools.

Many researchers have found that intermittent streams, springbrooks and seepage areas contain not only diverse invertebrate assemblages, but some unique aquatic species. Dieterich and Anderson (2000) found 202 aquatic and semi-aquatic invertebrate species, including at least 13 previously undescribed taxa. Morse et al (1997) have reported that many rare invertebrate species in the southeast are known from only one of a few locations with pea-sized gravel or in springbrooks and seepage areas. Kirchner (F. Kirchner pers. comm. 2000 and Kirchner and Kondratieff 2000) reports 60 species of stoneflies from eastern North America are found only in first and second order streams, including seeps and springs. 50% of these species have been described as new to science in last 25-30 years.

Williams (1996) reported that virtually all of the aquatic insect orders contain at least some species capable of living in temporary waters and that a wide variety of adaptations across a broad phylogenetic background has resulted in over two-thirds of these orders being well represented in temporary waters. This researcher goes on to say that "perhaps the concept of temporary waters constraining their faunas is based more on human perception than on fact".

We have conducted field surveys to confirm the extent of perennial and intermittent stream reaches that would be buried by mountaintop mining valley fills proposed in specific permits. This field work indicated that the 1:24,000 USGS topographic maps underestimate both the perennial and intermittent stream resources (Green and Passmore 1999a, Green and Passmore, 1999b). These field surveys indicated that all of the sites that were classified as intermittent based on flow supported aquatic life very similar to the sites classified as perennial based on flow. These surveys and others indicate that intermittent flow alone is a poor indicator of the abundance and diversity of aquatic life supported by a stream.

Other field work done in support of the Mountaintop Mining/Valley Fill EIS assessed the potential limits of viable aquatic communities in small headwater streams in southern West Virginia (Kirchner et al 2000). This study found that a number of taxa that were found in the extreme headwaters have multi-year life cycles suggesting that sufficient water is present for long-lived taxa to complete their juvenile development prior to reaching the aerial adult stage. Although only contiguous flow areas were considered for this study, the field work took place in the winter and based on our field experience and that of the authors, it is probable these extreme headwaters are subject to annual drying.

Table 2. Summary of Stream Conditions Based on the WV Stream Condition Index
Percentage of Sites in Each Condition Category by Stream Class

Season (n)	**Very Good (>78-100)**	**Good (>70-78)**	**Fair (>46-70)**	**Poor (>23-46)**	**Very Poor (0-23)**
Unmined					
Spring 1999 (9)	67	33	0	0	0
Summer 1999 (2)	0	50	50	0	0
Fall 1999 (2)	0	50	0	50	0
Winter 2000 (9)	78	11	11	0	0
Spring 2000 (10)	100	0	0	0	0
Total for all seasons (32)	72	19	6	3	0

Table 2. Summary of Stream Conditions Based on the WV Stream Condition Index Percentage of Sites in Each Condition Category by Stream Class					
Season (n)	**Very Good (>78-100)**	**Good (>70-78)**	**Fair (>46-70)**	**Poor (>23-46)**	**Very Poor (0-23)**
Filled					
Spring 1999 (15)	27	7	53	13	0
Summer 1999 (15)	0	0	100	0	0
Fall 1999 (14)	7	43	50	0	0
Winter 2000 14)	21	14	50	14	0
Spring 2000 (15)	13	33	13	33	7
Total for all seasons (73)	14	19	53	12	1
Filled/residential					
Spring 1999 (6)	0	0	17	83	0
Summer 1999 (6)	0	0	67	33	0
Fall 1999 (6)	0	0	83	17	0
Winter 2000 (6)	0	0	33	67	0
Spring 2000 (6)	0	0	17	83	0
Total for all seasons (30)	0	0	43	57	0
Mined					
Spring 1999 (4)	75	0	0	25	0
Summer 1999 (2)	50	50	0	0	0
Fall 1999 (1)	100	0	0	0	0
Winter 2000 (3)	100	0	0	0	0
Spring 2000 (5)	60	20	0	20	0
Total for all seasons (15)	73	13	0	13	0

5.2 Spring 1999 Benthic Data

The spring 1999 data set included nine (9) unmined sites, fifteen (15) filled sites, six (6) filled/residential sites and four (4) mined sites. A summary of the spring 1999 benthic data is provided in table 3 and in figures 8 - 16 in Appendix 4.

The spring 1999 data indicate that all of the unmined sites met our expectations for healthy streams based on the broader West Virginia reference condition. All of these streams were in good or very good condition. The class of unmined sites includes primarily forested watersheds with few or no known stressors. The tight range of metric values and conditions in the unmined class supports the conclusion that characteristics of minimally impaired streams are fairly comparable over the MTM/VF region.

Table 3. Summary of Spring 1999 Benthic Data (mean and standard deviation)

Metric: mean (standard deviation)	**EIS Class**			
	Unmined (n=9)	**Filled (n=15)**	**Filled/residential (n=6)**	**Mined (n=4)**
WV SCI	82.0 (7.8)	61.9 (14.6)	42.2 (9.9)	72.4 (22.7)
Total Taxa	20.6 (4.2)	15.2 (3.9)	14.0 (2.6)	17.3 (7.3)
EPT Taxa	13.2 (3.2)	7.9 (3.6)	6.3 (2.0)	10.8 (5.0)
%EPT	67.2 (13.6)	50.5 (23.3)	18.5 (11.2)	52.4 (30.6)
HBI	3.8 (0.7)	4.6 (0.7)	6.0 (0.5)	4.7 (1.8)
% 2 Dominant	47.3 (9.1)	63.7 (11.3)	71.6 (8.2)	57.3 (23.6)
% Chironomidae	20.4 (14.0)	28.9 (17.3)	50.4 (16.1)	17.3 (14.0)
Mayfly Taxa	4.9 (0.8)	1.6 (1.3)	2.3 (2.0)	3.8 (1.9)
% Mayflies	37.4 (11.2)	10.3 (16.7)	3.5 (5.7)	21.3 (17.8)

Condition Categories for the WV SCI:
>78-100 Very Good - Highly comparable to WVDEP reference sites
>70-78 Good - Comparable to below-average WVDEP reference sites
>46-70 Fair
>23-46 Poor
0-23 Very Poor

Conditions in the filled sites ranged from poor to very good conditions. The majority of the filled sites were in fair condition (53%). However, over a third of the filled sites were in good or very good condition (34%). The filled sites range from a site that has only one, very small fill in the headwaters (MT52) to sites that have several fills in their headwaters.

Conditions in the filled/residential sites ranged from poor to fair. Eighty-three (83%) of these sites were in poor condition in the spring of 1999. Conditions in the mined sites were either poor (25%) or very good (75%). Most of the sites in this class have minimal mining in their watersheds. The site (MT78) that scored poor is probably naturally limited by flow even during normal flow periods. We believe this site only flows in response to precipitation events and snow melt.

The descriptive statistics and the box and whisker plots indicate that the class of unmined sites was different from the class of filled sites in the spring of 1999 (see table 3 and figures 8-16). For every individual metric and the SCI, the mean values of the metrics in the filled sites class indicate some impairment relative to the unmined sites. In the box and whisker plots, there was no overlap of the interquartile ranges (25th percentile to the 75th percentile) of the unmined and filled classes for the metrics Mayfly Taxa, % Mayflies, EPT Taxa, Total Taxa, and % Two Dominant Taxa. For the SCI, modified HBI, and %EPT, there was some overlap of the interquartile ranges, but the medians of both classes were outside of the interquartile overlap. There was substantial overlap of the ranges for the metric % Chironomidae.

The descriptive statistics and the box and whisker plots indicate that the class of unmined sites was different from the class of filled/residential sites in the spring of 1999. For every metric, the mean values and the range of values in the filled/residential sites indicate some impairment relative to the unmined sites. There was no overlap of the interquartile ranges (25th% - 75th%) of the unmined and filled/residential classes for any of the metrics.

Except for a single site (MT78), the data did not indicate that the mined class was impaired relative to the unmined class in the spring of 1999. As mentioned before, we believe the impaired stream is naturally limited by low flows, even during periods of non-drought conditions.

5.3 Summer 1999 Benthic Data

The summer 1999 data set included two (2) unmined sites, fifteen (15) filled sites, six (6) filled/residential sites and two (2) mined sites. A summary of the summer 1999 benthic data is provided in table 4 and in figures 17 - 25 in Appendix 4.

Ten of the sites could not be sampled in the summer of 1999. Riffle habitats at six of these sites were completely dry. At the other four sites, there was some flow, but not enough to collect a representative sample effectively. Seven of these sites are unmined sites (MT02 on Rushpatch Branch, MT03 on Lukey Fork, MT13 on Spring Branch, MT39 on White Oak Branch, MT50 and MT51 on Cabin Branch, and MT95 on Neil Branch). Two of these sites were mined sites (MT81 on Sycamore Creek, and MT78 on Raines Fork). One of the sites was a mined site with residences in the watershed (MT01 on the Mud River) and was not included in the class analysis. All of the filled sites had sufficient flow to be sampled in the summer of 1999.

Table 4. Summary of Summer 1999 Benthic Data (mean and standard deviation)				
Metric: mean (standard deviation)	**EIS Class**			
	Unmined (n=2)	**Filled (n=15)**	**Filled/residential (n=6)**	**Mined (n=2)**
WV SCI	72.9 (8.0)	60.3 (6.2)	50.0 (8.2)	75.6 (7.3)
Total Taxa	16.5 (0.7)	13.5 (2.5)	13.5 (1.9)	18.5 (0.7)
EPT Taxa	9.0 (0.0)	4.7 (1.6)	4.7 (1.2)	8.5 (0.7)
%EPT	47.0 (1.7)	53.6 (18.1)	30.7 (11.5)	64.1 (1.7)
HBI	4.6 (0.4)	5.0 (0.5)	5.5 (0.5)	4.3 (0.5)
% 2 Dominant	52.8 (21.2)	66.3 (13.3)	67.7 (9.0)	52.3 (14.3)
% Chironomidae	7.1 (1.8)	14.6 (11.0)	31.1 (15.0)	9.6 (6.4)
Mayfly Taxa	3.0 (0.0)	0.5 (0.6)	1.7 (1.5)	1.5 (2.1)
% Mayflies	11.8 (11.3)	0.5 (0.7)	1.8 (2.1)	10.5 (14.9)
Condition Categories for the WV SCI: >78-100 Very Good - Highly comparable to WVDEP reference sites >70-78 Good - Comparable to below-average WVDEP reference sites >46-70 Fair >23-46 Poor 0-23 Very Poor				

Since the summer 1999 data set is incomplete, only cursory comparisons could be made between the unmined control class and the other classes. The summer 1999 data indicate that one of the unmined sites was in good condition and one was in fair condition. All of the filled sites scored in the fair range in the summer of 1999. Conditions in the filled/residential sites ranged from poor to fair. Sixty-seven percent (67%) of the filled/residential sites were in fair condition in the summer of 1999. Conditions in the two mined sites were good and very good. The site that scored in the poor range in the spring of 1999 was completely dry and could not be sampled in the summer of 1999 (site MT78).

5.4 Fall 1999 Benthic Data

The fall 1999 data set included two (2) unmined sites, fourteen (14) filled sites, six (6) filled/residential sites and one (1) mined sites. A summary of the fall 1999 benthic data is provided in table 5 and in figures 26 - 34 in Appendix 4.

Eleven of the sites could not be sampled in the fall of 1999. The riffle habitat at one of these sites was completely dry. At the other ten sites, there was some flow, but not enough to collect a representative sample effectively. Seven of these sites were unmined sites (MT02 on Rushpatch Branch, MT03 on Lukey Fork, MT13 on Spring Branch, MT39 on White Oak Branch, MT42 on Oldhouse Branch, and MT50 and MT51 on Cabin Branch). Three of the these sites were mined sites (MT79 on Davis Fork, MT81 on Sycamore Creek, and MT78 on Raines Fork). One of the sites was a filled site (MT34B on the Left Fork of Beech Creek).

Since the fall 1999 data set is incomplete, only cursory comparisons could be made between the unmined control class and the other classes. The fall 1999 data indicate that one of the unmined sites was in good condition and one was in poor condition. We believe the unmined site in poor condition (MT95 on Neil Branch) was just recently flowing at the time of sampling. This site had been dry in the summer of 1999 and could not be sampled then. This site scored in the very good range in later sampling periods (winter 2000 and spring 2000). We do not believe the score in the fall of 1999 was representative of the conditions at this site based on the other three seasons (spring 1999, winter 2000 and spring 2000) of data.

Half of the filled sites scored in the fair range in the fall of 1999. The other half of the filled sites scored in the very good (7%) and good range (43%). Conditions in the filled/residential sites ranged from poor to fair. Eighty-three percent (83%) of these sites were in fair condition in the fall of 1999. The one mined site that could be sampled scored very good in the fall of 1999.

Table 5. Summary of Fall 1999 Benthic Data (mean and standard deviation)

Metric: mean (standard deviation)	**EIS Class**			
	Unmined (n=2)	**Filled (n=14)**	**Filled/residential (n=6)**	**Mined (n=1)**
WV SCI	56.9 (28.6)	68.8 (6.5)	56.7 (12.1)	88.7
Total Taxa	11.0 (9.9)	13.5 (3.0)	14.8 (3.0)	20.0

Table 5. Summary of Fall 1999 Benthic Data (mean and standard deviation)				
Metric: mean (standard deviation)	**EIS Class**			
	Unmined (n=2)	**Filled (n=14)**	**Filled/residential (n=6)**	**Mined (n=1)**
EPT Taxa	5.5 (5.0)	6.8 (2.3)	6.5 (2.5)	11.0
%EPT	45.0 (38.0)	72.2 (17.6)	45.0 (23.6)	83.0
HBI	4.9 (2.5)	3.3 (1.1)	4.7 (1.3)	2.9
% 2 Dominant	72.9 (25.5)	64.7 (11.3)	64.3 (15.0)	53.6
% Chironomidae	5.4 (7.6)	13.0 (10.4)	30.4 (20.5)	3.1
Mayfly Taxa	2.0 (2.8)	0.9 (0.9)	2.0 (1.3)	4.0
% Mayflies	1.1 (1.6)	0.8 (1.2)	1.3 (1.6)	7.1
Condition Categories for the WV SCI: >78-100 Very Good - Highly comparable to WVDEP reference sites >70-78 Good - Comparable to below-average WVDEP reference sites >46-70 Fair >23-46 Poor 0-23 Very Poor				

5.5 Winter 2000 Benthic Data

By the winter 2000 sampling period, most of the streams could be sampled, except for one mined site (MT78) which was completely dry and one filled site (MT34B) which was too low to sample. The winter 2000 data set included nine (9) unmined sites, fourteen (14) filled sites, six (6) filled/residential sites and three (3) mined sites. A summary of the winter 2000 benthic data is provided in table 6 and in figures 35 - 43 in Appendix 4.

The winter 2000 data indicate that most of the unmined sites met our expectations for healthy streams based on the broader West Virginia reference condition. Most of these streams (89%) were in good or very good condition. One site scored in the high fair range (MT39 had an SCI score of 67.8).

Conditions in the filled sites ranged from poor to very good conditions. Half of the filled sites were in fair condition (50%). However, over a third of the filled sites were in good or very good condition (35%).

Table 6. Summary of Winter 2000 Benthic Data (mean and standard deviation)

Metric: mean (standard deviation)	EIS Class			
	Unmined (n=9)	Filled (n=14)	Filled/residential (n=6)	Mined (n=3)
WV SCI	86.3 (9.6)	62.6 (17.9)	35.2 (11.0)	85.5 (7.5)
Total Taxa	19.0 (4.0)	16.2 (3.7)	13.3 (3.5)	21.3 (1.5)
EPT Taxa	12.1 (2.8)	9.2 (3.8)	6.3 (2.2)	14.3 (2.1)
%EPT	75.0 (12.8)	50.3 (23.7)	17.2 (13.6)	70.9 (4.9)
HBI	3.2 (0.7)	4.6 (1.1)	6.1 (0.7)	3.6 (0.4)
% 2 Dominant	45.9 (18.2)	63.2 (15.4)	81.2 (11.3)	41.8 (12.9)
% Chironomidae	13.4 (10.1)	37.1 (17.0)	66.1 (13.7)	22.5 (11.4)
Mayfly Taxa	4.1 (0.6)	1.9 (1.6)	1.0 (1.3)	4.0 (0.0)
% Mayflies	26.3 (11.6)	6.9 (11.2)	0.5 (0.8)	27.1 (12.5)

Condition Categories for the WV SCI:
>78-100 Very Good - Highly comparable to WVDEP reference sites
>70-78 Good - Comparable to below-average WVDEP reference sites
>46-70 Fair
>23-46 Poor
0-23 Very Poor

Conditions in the filled/residential sites ranged from poor to fair. Over two-thirds of these sites (67%) were in poor condition in the winter of 2000.

All of the mined sites were in very good condition in the winter of 2000. Most of the sites in this class have minimal mining in their watersheds. The mined site that scored poor in the spring of 1999 (MT78) was still dry in the winter of 2000.

The descriptive statistics and the box and whisker plots indicate that the class of unmined sites was different from the class of filled sites in the winter of 2000 (see table 6 and figures 35 - 43). For every individual metric and the SCI, the mean value of the metrics in the filled sites class indicate some impairment relative to the unmined sites. In the box and whisker plots, there was no overlap of the interquartile ranges (25th percentile to the 75th percentile) of the unmined and filled classes for the metrics SCI, HBI, % Chironomidae, Mayfly Taxa, and % Mayflies. For the metrics %EPT, and % Two Dominant, there was some overlap of the interquartile ranges, but the medians of both classes were outside of the interquartile overlap. There was substantial overlap of the ranges for the metrics Total Taxa and EPT Taxa.

The descriptive statistics and the box and whisker plots indicate that the class of unmined sites was different from the class of filled/residential sites in the winter of 2000. For every metric, the mean values and the range of values in the filled/residential sites indicate some impairment relative to the unmined sites. There was no overlap of the interquartile ranges (25th% - 75th%) of the unmined and filled/residential classes for any of the metrics.

The winter 2000 data did not indicate that the mined class was impaired relative to the unmined class.

We also reviewed an independent benthic data set collected by Potesta and Associates for Arch Coal in the winter 2000 season (Potesta and Associates, Inc. 2000). Potesta and Associates also collected samples during the summer and fall 1999 seasons, but like ours, these data sets were incomplete (many sites could not be sampled due to the drought) and were of limited utility for comparing the other classes to the unmined class of streams. Potesta and Associates sampled the benthic assemblage using a Surber sampler. Six samples were collected at each site in the Mud River, Spruce Fork and Island Creek watersheds at the same time that our winter 2000 samples were collected. This independent data set indicates similar patterns in condition and generally supports our conclusions. Our analysis of the winter 2000 data set provided by Potesta and Associates indicated that the sites in the filled and filled/residential classes were impaired relative to the unmined sites (Green and Passmore 2000). The filled/residential class was the most impaired class.

5.6 Spring 2000 Benthic Data

The spring 2000 data set included ten (10) unmined sites, fifteen (15) filled sites, six (6) filled/residential sites and five (5) mined sites. Two sites were added in the spring of 2000. Site MT107 was established on the Left Fork of Cow Creek in the Island Creek Watershed and was classified as unmined. Site MT106 was established on an unnamed tributary to Sugartree Branch in the Mud River Watershed and was classified as mined. A summary of the spring 2000 benthic data is provided in table 7 and in figures 44 - 52 in Appendix 4.

The spring 2000 data indicate that all of the unmined sites met our expectations for healthy streams based on the broader West Virginia reference condition. All of these streams were in very good condition in the spring of 2000.

Table 7. Summary of Spring 2000 Benthic Data (mean and standard deviation)				
Metric: mean (standard deviation)	**EIS Class**			
	Unmined (n=10)	**Filled (n=15)**	**Filled/residential (n=6)**	**Mined (n=5)**
WV SCI	86.3 (4.6)	57.2 (22.6)	40.6 (5.4)	72.4 (18.6)
Total Taxa	17.9 (3.4)	13.5 (3.7)	12.7 (1.9)	16.2 (4.4)
EPT Taxa	11.6 (2.1)	7.7 (3.3)	7.3 (1.5)	10.8 (2.8)
%EPT	71.8 (10.2)	44.6 (30.8)	19.7 (7.9)	54.3 (17.4)
HBI	3.7 (0.5)	4.8 (1.2)	6.3 (0.5)	4.6 (0.9)
% 2 Dominant	42.4 (8.3)	68.1 (19.3)	77.9 (6.7)	56.5 (18.6)
% Chironomidae	14.1 (7.5)	34.0 (23.4)	60.6 (14.6)	36.1 (21.6)
Mayfly Taxa	4.5 (1.0)	1.5 (1.3)	2.2 (1.3)	3.6 (0.9)
% Mayflies	34.7 (9.7)	11.9 (13.4)	6.7 (5.6)	19.4 (12.8)

Condition Categories for the WV SCI:
>78-100 Very Good - Highly comparable to WVDEP reference sites
>70-78 Good - Comparable to below-average WVDEP reference sites
>46-70 Fair
>23-46 Poor
0-23 Very Poor

Conditions in the filled sites ranged from very poor to very good conditions. The slim majority of the filled sites were in fair to very poor condition (53%). However, a large percentage of the filled sites were in good or very good condition (46%).

Conditions in the filled/residential sites ranged from poor to fair. Eighty-three (83%) of these sites were in poor condition in the spring of 2000.

Conditions in the mined sites were either poor (20%) or good or very good (80%). Most of the sites in this class have minimal mining in their watersheds. The site that scored poor was the site that had been dry since it was first sampled in the spring of 1999. We believe this site may only flow for a short period in the wet spring season.

The descriptive statistics and the box and whisker plots indicate that the class of unmined sites was different from the class of filled sites in the spring of 2000 (see table 7 and figures 44 - 52). For every individual metric and the SCI, the mean values of the metric in the filled sites class indicate some impairment relative to the unmined sites. In the box and whisker plots, there was no overlap of the interquartile ranges (25th percentile to the 75th percentile) of the unmined and filled classes for the metrics SCI, EPT Taxa, % Two Dominant, Mayfly Taxa and % Mayflies. For Total Taxa, HBI, and % Chironomidae, there was some overlap of the interquartile ranges, but the medians of both classes were outside of the interquartile overlap. There was more substantial overlap of the ranges for the metric %EPT.

The descriptive statistics and the box and whisker plots indicate that the class of unmined sites was different from the class of filled/residential sites in the spring of 2000. For every metric, the mean values and the range of values in the filled/residential sites indicate some impairment relative to the unmined sites. There was no overlap of the interquartile ranges (25th% - 75th%) of the unmined and filled/residential classes for any of the metrics.

Except for a single site (MT78), the data did not indicate that the mined class was impaired relative to the unmined class in the winter of 2000. As mentioned before, we believe the impaired stream is naturally limited by low flows, even during periods of non-drought conditions. This stream did not have any flowing water in it during the summer 1999, fall 1999, or winter 2000 sampling periods.

6.0 PHYSICAL/CHEMICAL CONDITION OF STREAMS

In the previous section, the ecological condition of the streams and stream classes was described using the benthic assemblage as a direct indicator of stream condition. This section describes the characteristics of potential stressors in these streams based on direct measurements of water quality, physical habitat, and substrate size and composition. We considered using land cover as a way to characterize potential stressors, but after extensive review of the readily available Landsat land cover data, we determined that these data were too dated and inaccurate to provide a current description of potential stressors.

6.1 Field Chemical/Physical Data : Summary of Findings

We measured conductivity, pH, temperature and dissolved oxygen, in the field, at the time of sampling. Sites were grouped over the entire region by the four classes (unmined, filled, filled/residential, and mined) and by season. Our data provided only limited information on water quality as only a single reading was taken during each field visit and some of the water quality parameters can be quite variable over the course of a day and over the seasons.

Conductivity is often used to estimate the total dissolved solids in water. The quantity of dissolved material in water depends mainly on the solubility of rocks and soils the water contacts. Most activities, including mining, logging, development, roads, etc., increase the total dissolved solids in a watershed. Mining disturbance can produce high sulfate values and extremely high conductivity. There is no aquatic life criterion for total dissolved solids or conductivity. In general, the filled and filled/residential classes had substantially higher conductivity than the unmined class (Tables 8 and 9 and figures 53, 56, 60, 64, and 68). This was the only obvious pattern in field chemical/physical parameters that held up over all five seasons. It should be noted that conductivity in the filled sites was generally comparable to or higher than conductivity in the filled/residential sites within a watershed. These data suggest that the probable cause of the increase in total dissolved solids at the filled/residential sites (compared to the unmined sites) was the mining activity, rather than the residences.

A range of pH from 6.0 to 9.0 is considered protective for most organisms in West Virginia's water quality standards. Changes in the water's pH can also affect aquatic life indirectly by changing other aspects of water quality. For instance, some metals are more mobile at lower pH levels. The toxicity of ammonia to fish also varies within a small range of pH values. Over the course of this study, pH measurements were always within the bounds of the aquatic life criteria (see figures 54, 57, 61, 65, and 69). Acidity did not appear to be limiting the aquatic life in these streams.

Aquatic organisms need dissolved oxygen to live. For warm water fisheries, a minimum of 5 mg/l dissolved oxygen at all times is required by West Virginia water quality standards. Over the course of this study, dissolved oxygen measurements were always greater than this minimum criterion (see figures 59, 63, 67, and 71). The data did not indicate any substantial differences between the classes.

Table 8. Summary of Water Quality Based on Field Chemical/Physical Data Mean by Season and Stream Class				
Stream Class (n)	**Conductivity (uS/cm)**	**pH (su)**	**Temperature (C)**	**Dissolved Oxygen (mg/l)**
Spring 1999				
Unmined (9)	64	7.5	13.5	*
Filled (15)	946	7.9	13.1	*
Filled/residential (6)	652	8.3	14.6	*
Mined (4)	172	8.4	11.8	*
Summer 1999				
Unmined (2)	140	7.3	23.4	6.5
Filled (15)	1232	7.7	21.0	7.5
Filled/residential (6)	1124	8.3	22.2	8.5
Mined (3)	385	7.1	19.5	8.7
Fall 1999				
Unmined (2)	91	7.5	8.8	11.5
Filled (14)	958	7.4	8.7	10.3
Filled/residential (6)	984	7.5	11.7	9.8
Mined (1)	260	6.7	6.3	10.4
Winter 2000				
Unmined (9)	73	7.7	1.6	13.3
Filled (14)	836	7.8	2.9	13.0
Filled/residential (6)	844	7.8	1.6	14.0
Mined (3)	254	7.3	2.2	12.7
Spring 2000				
Unmined (10)	58	7.1	12.1	9.5
Filled (15)	643	7.1	12.1	9.9
Filled/residential (6)	538	7.1	15.1	9.1
Mined (5)	192	6.9	12.6	9.9

* Dissolved oxygen was not measured at most sites in the spring of 1999.

Water temperature can determine which species may be present in a system. Temperature also affects feeding, reproduction, and the metabolism of aquatic animals. A week or two of high temperatures at critical times during the year may make a stream unsuitable for sensitive aquatic organisms or life stages. The West Virginia water quality standards indicate that temperature rise shall be limited to no more than 5 F or 2.7 C degrees above "natural" temperature, and should not exceed 87 F (31 C) at any time during the months of May through November and should not exceed 73 F (24 C) at any time during the months of December and April. Over the course of this study, none of the temperatures measured exceeded these seasonal maximums (see figures 55, 58, 62, 66, and 70). Temperature means were also fairly comparable within the four classes, and did not indicate any widespread rise above "natural" in any of the classes using the unmined class as the control class.

Table 9. Summary of Water Quality Based on Field Chemical/Physical Data Mean By Stream Class and Season

Season (n)	Conductivity (uS/cm)	pH (su)	Temperature (C)	Dissolved Oxygen (mg/l)
Unmined				
Spring 1999 (9)	64	7.5	13.5	*
Summer 1999 (2)	140	7.3	23.4	6.5
Fall 1999 (2)	91	7.5	8.8	11.5
Winter 2000 (9)	73	7.7	1.6	13.3
Spring 2000 (10)	58	7.1	12.1	9.5
Filled				
Spring 1999 (15)	946	7.9	13.1	*
Summer 1999 (15)	1232	7.7	21.0	7.5
Fall 1999 (14)	958	7.4	8.7	10.3
Winter 2000 14)	836	7.8	2.9	13.0
Spring 2000 (15)	643	7.1	12.1	9.9
Filled/residential				
Spring 1999 (6)	652	8.3	14.6	*
Summer 1999 (6)	1124	8.3	22.2	8.5
Fall 1999 (6)	984	7.5	11.7	9.8
Winter 2000 (6)	844	7.8	1.6	14.0
Spring 2000 (6)	538	7.1	15.1	9.1
Mined				

Table 9. Summary of Water Quality Based on Field Chemical/Physical Data Mean By Stream Class and Season				
Season (n)	**Conductivity (uS/cm)**	**pH (su)**	**Temperature (C)**	**Dissolved Oxygen (mg/l)**
Spring 1999 (4)	172	8.4	11.8	*
Summer 1999 (2)	385	7.1	19.5	8.7
Fall 1999 (1)	260	6.7	6.3	10.4
Winter 2000 (3)	254	7.3	2.2	12.7
Spring 2000 (5)	192	6.9	12.6	9.9
* Dissolved oxygen was not measured at most sites in the spring of 1999.				

Dissolved oxygen, pH and temperature can all vary during the day and through the seasons. The grab samples for these parameters may not be representative of water quality at these sites. Grab temperature measurements can be problematic since temperature clearly fluctuates during the day and seasonally in streams. Dissolved oxygen and pH levels can also vary over the course of a day due to changes in temperature, and changes in the photosynthesis daily cycle. Dissolved oxygen minimums occur in the very early morning hours, when community respiration is at its peak and the maximums occur during the afternoon when photosynthesis activity consumes carbon dioxide and produces oxygen. Therefore, grab dissolved oxygen measures taken during the day may not be representative of the critical minimum dissolved oxygen levels in a stream. Inorganic carbon in the form of carbon dioxide (a weak acid) is consumed during the day, so pH values can become elevated during the day and depressed at night. So, like grab temperature measurements, these grab dissolved oxygen and pH measurements should be treated with caution.

The seven WVDEP reference sites are provided on the box and whisker plots as an additional point of reference for the summer 1999 index period. These sites are not included on the box and whisker plots for other seasons because of the strong seasonal patterns in temperature and dissolved oxygen.

6.1.1 Spring 1999 Field Chemical/Physical Data

Conductivity, temperature and pH were measured at all of the sites, at the time of sampling, in the spring of 1999 (table 10). Conductivity means and interquartile ranges were much higher in the filled and filled/residential class than the unmined class (figure 53). Conductivity was consistently low in the unmined class. As a class, the filled sites had the highest mean conductivity.

The mean pH values and interquartile ranges were higher in the filled, filled/residential, and mined classes compared to the unmined class in the spring of 1999 (figure 54). The water quality standard for pH is 6.0 to 9.0. There were no pH values measured that could be considered to be harmful to aquatic life in the spring of 1999. Acidity did not seem to be a problem in the sites we sampled.

The means and interquartile ranges of temperature were quite similar for the unmined, filled and filled/residential classes (figure 55). The mean temperature was slightly, although not substantially, higher in the filled/residential class in the spring 1999 data set.

Table 10. Summary of Spring 1999 Field Chemical/Physical Data (mean and standard deviation)

Metric: mean (standard dev.)	**EIS Class**			
	Unmined (n=9)	**Filled (n=15)**	**Filled/residential (n=6)**	**Mined (n=4)**
Conductivity (uS/cm)	63.7 (19.1)	945.5 (614.0)	651.8 (236.5)	172.0 (90.4)
pH (su)	7.5 (0.7)	7.9 (0.6)	8.3 (0.3)	8.4 (0.3)
Temperature (C)	13.5 (2.0)	13.1 (1.4)	14.6 (2.9)	11.8 (5.1)
Dissolved Oxygen (mg/l)*				

Dissolved Oxygen was not measured in the spring of 1999 at most sites.

6.1.2 Summer 1999 Field Chemical/Physical Data

Conductivity, temperature, pH and dissolved oxygen were measured at all of the sites, at the time of sampling, in the summer of 1999. Only two unmined sites could be sampled in the summer of 1999, so only cursory comparisons can be made between the classes. Conductivity means were substantially higher in the filled and filled/residential classes compared to the unmined class (table 11 and figure 56). Conductivity was consistently low in the unmined class. The filled sites had a slightly higher mean conductivity than the filled/residential sites. The highest mean conductivities of the study period occurred during the summer 1999 sampling period.

The mean pH measurements were higher in the filled and filled/residential classes compared to the unmined class in the summer of 1999. As in the spring, there were no pH values measured that could be considered to be harmful to aquatic life in the summer of 1999 (figure 57).

The ranges of temperature appeared to be similar for the unmined, filled, filled/residential, and mined classes in the summer of 1999 (figure 58).

Dissolved oxygen means were higher in the filled, filled/residential and mined sites than in the unmined sites in the summer of 1999. The dissolved oxygen measurements taken in the summer of 1999 were all above the minimum criterion of 5 mg/l (figure 59).

Table 11. Summary of Summer 1999 Field Chemical/Physical Data (mean and standard deviation)

Metric: mean (standard dev.)	EIS Class			
	Unmined (n=2)	**Filled (n=15)**	**Filled/residential (n=6)**	**Mined (n=3)**
Conductivity (uS/cm)	139.5 (54.4)	1231.7 (643.4)	1123.8 (282.3)	385.3 (201.6)
pH (su)	7.3 (0.3)	7.7 (0.4)	8.3 (0.3)	7.1 (0.3)
Temperature (C)	23.4 (0.9)	21.0 (3.0)	22.2 (4.4)	19.5 (2.1)
Dissolved Oxygen (mg/l)	6.5 (1.2)	7.5 (1.0)	8.5 (1.0)	8.7 (1.3)

6.1.3 Fall 1999 Field Chemical/Physical Data

Conductivity, temperature, pH and dissolved oxygen were measured at most of the sites, at the time of sampling, in the fall of 1999 (table 12). A pH value could not be recorded at one of the filled/residential sites due to meter malfunction. Again, only two unmined sites could be sampled in the fall of 1999, so only cursory comparisons can be made between the classes. Conductivity means were again higher in the filled and filled/residential classes compared to the unmined class (figure 60). Conductivity was consistently low in the unmined class. The filled/residential sites had a slightly higher mean conductivity than the filled sites.

The mean pH measurements between the filled and filled/residential classes were comparable to the unmined class in the summer of 1999. As in the spring and summer, there were no pH values measured that could be considered to be harmful to aquatic life in the fall of 1999 (figure 61).

The ranges of temperature appeared to be similar for the unmined and filled classes (figure 62).

Dissolved oxygen means were lower in the filled, filled/residential and mined classes than in the unmined class in the fall of 1999. The dissolved oxygen measurements taken in the fall of 1999 were all above the minimum criterion of 5 mg/l (figure 63).

Table 12. Summary of Fall 1999 Field Chemical/Physical Data (mean and standard deviation)				
Metric: mean (standard dev.)	**EIS Class**			
	Unmined (n=2)	**Filled (n=14)**	**Filled/residential (n=6)**	**Mined (n=1)**
Conductivity (uS/cm)	91.1 (59.3)	958.3 (430.2)	984.3 (220.7)	260.0
pH (su)	7.5 (0.2)	7.4 (0.4)	7.5 (0.4)	6.7
Temperature (C)	8.8 (0.4)	8.7 (2.6)	11.7 (3.3)	6.3
Dissolved Oxygen (mg/l)	11.5 (0.3)	10.3 (1.2)	9.8 (0.6)	10.4

6.1.4 Winter 2000 Field Chemical/Physical Data

Conductivity, temperature, pH and dissolved oxygen were measured at most of the sites, at the time of sampling, in the winter of 2000. A pH value could not be recorded at one of the filled/residential sites due to meter malfunction. A dissolved oxygen value could not be recorded at one of the filled sites due to meter malfunction. Conductivity means were again substantially higher in the filled and filled/residential classes compared to the unmined class (table 13 and figure 64). Conductivity was consistently low in the unmined class. The filled/residential sites had a slightly higher mean conductivity than the filled sites.

The mean pH measurements between the filled and filled/residential classes were comparable to the unmined class in the winter of 2000. As in earlier seasons, there were no pH values measured that could be considered to be harmful to aquatic life in the winter of 2000 (figure 65).

The ranges of temperature were similar for the unmined, filled, filled/residential and mined classes (figure 66).

Dissolved oxygen means were comparable in the unmined, filled, filled/residential and mined sites in the winter of 2000. The dissolved oxygen measurements taken in the winter of 2000 were all well above the minimum criterion of 5 mg/l, due to the colder temperatures of the water (figure 67).

Table 13. Summary of Winter 2000 Field Chemical/Physical Data (mean and standard deviation)				
Metric: mean (standard dev.)	**EIS Class**			
	Unmined (n=9)	**Filled (n=14)**	**Filled/residential (n=6)**	**Mined (n=3)**
Conductivity (uS/cm)	72.8 (28.8)	836.2 (424.7)	844.0 (172.6)	254.3 (171.1)
pH (su)	7.7 (0.9)	7.8 (0.4)	7.8 (0.6)	7.3 (0.8)
Temperature (C)	1.6 (1.5)	2.9 (1.6)	1.6 (0.9)	2.2 (1.9)
Dissolved Oxygen (mg/l)	13.3 (0.8)	13.0 (0.9)	14.0 (1.5)	12.7 (1.6)

6.1.5 Spring 2000 Field Chemical/Physical Data

Conductivity, temperature, pH and dissolved oxygen were measured at all of the sites, at the time of sampling, in the spring of 2000.

Conductivity means were again substantially higher in the filled and filled/residential classes than in the unmined class (table 14 and figure 68). Conductivity was consistently low in the unmined class. The filled sites had a higher mean conductivity than the filled/residential sites.

The mean pH measurements between the filled and filled/residential classes were comparable to the unmined class in the spring of 2000. As in earlier seasons, there were no pH values measured that could be considered to be harmful to aquatic life in the spring of 2000 (figure 69).

The ranges of temperature were similar for the unmined, filled and mined classes in the spring of 2000 (figure 70).

Dissolved oxygen means were fairly comparable in the unmined, filled, filled/residential and mined sites in the winter of 2000. The dissolved oxygen measurements taken in the spring of 2000 were all above the minimum criterion of 5 mg/l (figure 71).

Table 14. Summary of Spring 2000 Field Chemical/Physical Data (mean and standard deviation)				
Metric: mean (standard dev.)	**EIS Class**			
	Unmined (n=10	**Filled (n=15)**	**Filled/residential (n=6)**	**Mined (n=5)**
Conductivity (uS/cm)	58.4 (27.8)	642.7 (381.8)	538.3 (249.0)	191.6 (155.1)
pH (su)	7.1 (0.7)	7.1 (0.8)	7.1 (0.6)	6.9 (1.0)
Temperature (C)	12.1 (1.8)	12.1 (2.1)	15.1 (2.6)	12.6 (1.9)
Dissolved Oxygen (mg/l)	9.5 (0.9)	9.9 (0.9)	9.1 (0.3)	9.9 (0.7)

6.2 Rapid Bioassessment Protocol Habitat Evaluations

Good physical habitat is important for maintaining stream condition. Instream and riparian habitat influence the structure and function of the aquatic community of a stream. For example, excessive sediment deposition can reduce habitat space and its availability. Parameters evaluated in the sampling reach include epifaunal substrate/available cover; embeddedness; velocity/depth regimes; sediment deposition; channel flow status; channel alteration; frequency of riffles; bank stability; bank vegetative protection; and riparian vegetation zone width. Only the spring 2000 habitat assessments were used to determine habitat condition.

In general, the physical habitat data do not indicate substantial differences between the unmined classes and the other classes. Some individual stations did have marginally degraded habitat, including excess sediment deposition. Three sites in the filled class (MT18, MT34B, and MT32) and two sites in the filled/residential class (MT23 and MT55) had degraded habitat scores in the spring of 2000.

In the Rapid Bioassessment Protocol (RBP) the individual habitat parameters are classified into four general condition classes based on a 20 point scoring system. Optimal habitat (meeting natural expectations) is scored from 16 to 20, suboptimal habitat (still has adequate habitat for maintenance of populations) is scored from 11 to 15, marginal habitat (moderate level of degradation/ frequent intervals of problems within the reach) is scored from 6 to 10, and poor habitat (where the characteristic of the parameter is substantially altered and there is severe degradation) is scored from 0 to 5.

The total habitat score is the sum of the 10 individual parameters. In comparison to the unmined sites, the filled/residential sites had the lowest mean total scores followed by the filled sites (see figure 72). The mined sites had a higher mean score than the unmined sites (table 15). There was some overlap of the interquartile ranges of the unmined and filled sites and only a slight overlap between the unmined and filled/residential sites. There was complete overlap between the unmined and mined sites. Although these data suggested some habitat degradation at the filled/residential and filled sites, these differences did not appear to be serious enough to impair aquatic life at most stations.

The parameter embeddedness refers to the extent to which rocks and snags are covered or sunken into the silt, sand, or mud of the stream bottom. Generally, as rocks become more embedded, less habitat is available for the aquatic organisms. This parameter was measured in the riffle where the benthic sample was collected in order to avoid any confusion with the parameter sediment deposition. The embeddedness scores indicate that among all the classes, only one site scored less than suboptimal. A filled site (MT34B) scored in the marginal category. There was overlap of the interquartile ranges between the unmined, filled, and filled/residential sites. Some overlap occurred between the mined and unmined sites but this was on the top end of the scoring range. These data indicate that for the most part there is little difference in embeddedness among the EIS classes (see figure 73).

The parameter sediment deposition measures the amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of the deposition. High levels of sediment deposition are symptoms of an unstable environment that is unsuitable for many organisms. The filled sites had the lowest mean score for this parameter followed by the filled/residential sites (see figure 74). The mined sites once again had the highest mean score. The interquartile ranges of the filled and filled/residential sites overlapped with the unmined sites. The mined class overlapped the unmined class on the high end of the scoring range.

A total of eight sites scored in the marginal category for sediment deposition. In the unmined sites, site MT50 scored high marginal. A gas line was replaced along this stream during the study period and this activity clearly increased erosion along the stream. Three filled sites (MT18, MT32, and MT57) scored at the high end of the marginal range (10) and three other filled sites (MT14, MT34B, and MT15) had scores of 8, 7, and 6, respectively. One mined site (MT106) had a marginal score of 10. One filled/residential site (MT23) scored in the poor range for sediment deposition. The pools in this stream reach were impaired by sand deposition.

The parameter epifaunal substrate considers the relative quantity and variety of natural structures in the stream, such as cobble, large rocks, fallen trees, logs and branches, undercut banks, etc. These structures provide habitat available as refugia, feeding, or sites for spawning and nursery functions. All three of the disturbed classes had some overlap with the unmined class (figure 75). The filled/residential class had the lowest mean score followed by the filled class. The mined sites had a higher mean score than the unmined sites. The filled sites as a class had epifaunal substrate characteristics comparable to natural conditions. The filled/residential class had a mean score in the suboptimal range. One of the filled/residential sites (MT55) scored in the marginal range because of bedrock dominated substrate.

The parameter bank stability measures whether the stream banks are eroded. Eroded banks indicate a problem of sediment movement and deposition, and suggest a scarcity of cover and organic input to streams. The interquartile ranges of the unmined, filled, and filled/residential classes overlap, and there is some overlap between the unmined class and the mined class, but again on the high end of the scale (figure 80). The means of the filled, filled/residential, and mined classes were higher than the unmined sites. These data indicate that there was no substantial difference between the classes. Only site MT25B (filled) scored in the marginal range (9).

The parameter bank vegetative protection measures the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone. The root systems of plants and trees growing on the bank stabilize the bank, reducing erosion and increasing stability. Overhanging vegetation also provides cover for organisms and organic input to the stream. Banks that have full, natural plant growth are better for fish and macroinvertebrates than are banks without vegetation or which are shored up with rip rap, concrete, or other artificial structures. The interquartile ranges of the four EIS classes had some degree of overlap (figure 81). The filled/residential sites had the lowest mean of all the classes and one site (MT23) scored at the top end of marginal category. Only two of the six filled/residential sites scored in the optimal range. All of the filled sites scored in the optimal to suboptimal range. One unmined site (MT51) scored in the marginal range because of recent gas pipeline construction.

The parameter channel flow status measures the degree to which the channel is filled with water. All the unmined, filled, and filled/residential sites scored in the optimal range for the parameter (figure 76). The mined sites all scored in the optimal and suboptimal range. These data indicate that habitat loss due to low stream flows was not a substantial problem at any of the sites during the spring 2000 index period.

The parameter channel alteration is a measure of large-scale changes in the shape of the stream channel such as straightening, dredging, diversion, etc. The mean scores for the unmined and mined classes were in the optimal category and there was overlap of the interquartile ranges for these classes (figure 77). There was some overlap of the interquartile ranges between the unmined and filled classes and the mean score for the filled class was in the high suboptimal range. Two of the filled sites scored in the marginal category. These were sites MT34B and MT32. The filled/residential sites had the lowest mean score of all the classes but only one site (MT55) scored in less than suboptimal. Several of these sites are on larger streams and highway construction along their banks has resulted in channel alteration.

The parameter frequency of riffles is a way to measure the sequence of riffles and the heterogeneity in a stream. Riffles are very productive habitat. All four classes had mean scores in the optimal range and none of the streams scored out of the optimal range (figure 78). There were no substantial differences between the stream classes.

Table 15. Summary of Rapid Habitat Assessment Data Collected in the Spring of 2000 (mean and standard deviation)				
Habitat Parameter: mean (standard dev.)	**EIS Class**			
	Unmined (n=10)	**Filled (n=15)**	**Filled and Residences (n=6)**	**Mined (n=5)**
Total Habitat Score	155 (9.6)	148 (10.7)	144 (11.8)	159 (7.2)
Embeddedness	14.8 (2.3)	14.3 (2.6)	14.0 (1.1)	16.2 (1.3)
Sediment Deposition	14.2 (2.6)	12.2 (3.6)	12.7 (4.1)	15.2 (3.1)
Epifaunal Substrate	16.3 (2.8)	15.6 (2.7)	13.5 (3.7)	18.0 (1.2)
Channel Flow Status	17.5 (0.9)	17.9 (1.0)	17.8 (1.5)	15.6 (1.9)
Channel Alteration	16.7 (0.9)	14.7 (3.1)	13.3 (2.5)	16.0 (1.9)
Frequency of Riffles	17.9 (1.1)	17.5 (1.0)	17.2 (0.8)	18.2 (0.8)
Velocity Depth Regimes	12.8 (3.0)	12.6 (3.0)	16.0 (1.4)	11.2 (2.7)
Bank Stability	14.5 (2.8)	15.0 (2.4)	15.2 (1.9)	16.6 (0.9)
Bank Vegetative Protection	15.1 (2.3)	14.8 (2.0)	13.3 (3.1)	15.6 (1.9)
Riparian Vegetation Zone	15.2 (2.9)	13.9 (2.9)	11.0 (4.0)	16.2 (1.9)
Condition Categories for Individual Parameters: 20-16 Optimal 15-11 Suboptimal 10-6 Marginal 5-0 Poor				

The parameter velocity/depth combinations measures the patterns of velocity and depth in the stream reach. The best streams will have all four velocity/depth patterns present (slow-deep, fast-deep, slow-shallow and fast-shallow). There was overlap of the interquartile ranges between the unmined, filled, and mined classes and some overlap between the unmined and filled/residential classes (figure 79). The mean score for the filled/residential sites was 16, while the mean scores for the other classes ranged from 11.2 to 12.8. Many of the streams that scored low in the unmined, filled, and mined classes are small streams and are naturally limited because they often do not have deep water. Several of the filled/residential sites are located on larger streams which are more complex and more likely to have deep water.

The parameter riparian vegetation zone width measures the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone. The interquartile ranges between the unmined and mined classes overlapped and there was some overlap of the unmined class with the filled and filled/residential classes (figure 82). The filled/residential and filled sites had the lowest mean scores, 11.0 and 13.9, respectively. The filled/residential sites were often located close to highways which results in a loss of vegetation and the filled sites were sometimes located close to haul roads, which had the same effect.

6.3 Substrate Size and Composition

Riffles and runs are critical for maintaining a variety and abundance of aquatic insects in high gradient streams. More diverse invertebrate assemblages are generally associated with larger substrates which provide lots of interstitial spaces and surface area (Barbour et al 1999, Hynes 1970, Kaufmann et al 1999, Ward 1992). Excessive amounts of sediment in a stream can fill in interstitial spaces, reducing the habitat available for the organisms. High levels of sediment deposition are also symptoms of an unstable and continually changing environment that is unsuitable for many organisms. In the MTM/VF region in southern West Virginia, many activities can destabilize watersheds and increase sediment supply, including logging and mining. We measured substrate size and composition in order to determine if excessive sediment was causing the biological impairment observed in the filled and filled/residential classes.

Numeric scores were assigned to the substrate size classes that are proportional to the logarithm of the midpoint diameter of each size class (table 16). The mean substrate size class was calculated as the arithmetic mean of the numerically transformed size classes. The logarithmic nature of the substrate size classes specified in EMAP methods makes these mean size class scores proportional to the geometric mean substrate diameter. Based on assigning geometric midpoint diameters to each particle class, the following relationship was derived to transform mean diameter class scores into estimates of the $\log_{10}$ of mean substrate diameter in millimeters: If mean substrate size class score was less than or equal to 2.5 then $\log_{10}$ of mean substrate diameter was calculated as (-4.61 +(2.16 *mean diameter class)); if mean substrate size class score was greater than 2.5 then $\log_{10}$ of mean substrate diameter was calculated as (-1.78 +(0.960 *mean diameter class)) (Kaufmann et al 1999). The reach level mean substrate diameter in millimeters was derived by taking the antilog of these equations.

The reach level percentages of sands and fines (diameter less than or equal to 2 mm) were derived from the frequency of particles in these two size classes divided by the 55 total particle measurements. For example, if 5 of the measurements in the reach were classified as sand or fines, then the percentage of the substrate less than or equal to 2 mm would be 5/55*(100) or approximately 9%.

Table 16. Substrate Size Classes and Class Scores			
Class	**Size**	**Class Score**	**Description**
Bedrock	>4000 mm	6	Bigger than a car
Boulder	>250-4000 mm	5	Basketball to car
Cobble	>64-250 mm	4	Tennis ball to basketball
Coarse Gravel	>16-64 mm	3.5	Marble to tennis ball
Fine Gravel	>2-16 mm	2.5	Ladybug to marble
Sand	>0.06-2 mm	2	Gritty between fingers
Fines	<0.06 mm	1	Smooth, not gritty

The substrate size data indicate that the mean substrate size class scores and the mean calculated substrate particle sizes were smaller in the filled sites than in the unmined sites (table 17). The filled/residential streams also had substrates which were smaller than the unmined sites. The mined sites had the largest substrate of all the sites. The interquartile range of the unmined classes overlapped almost completely with the interquartile ranges of the filled and filled/residential classes indicating that the differences between the classes were not substantial (figures 83 and 84). The outliers included two sites with natural bedrock substrates (sites MT104 (filled) and MT55 (filled/residential)). Site MT23 (filled/residential) had the smallest substrate of all the sites with a mean substrate size in the small gravel range.

The filled and filled/residential class streams contained a greater mean percentage of sands and fines than did the unmined streams. The mined streams contained the lowest amount of sands and fines (table 17 and figure 85). There was substantial overlap of the interquartile ranges between the unmined and filled classes but the data also indicate signs of fining in some of the individual filled streams. There was also some overlap of the interquartile ranges between the unmined and filled/residential classes indicating mean conditions in the two classes might not be substantially different. Again, though, there were indications of fining in some of the individual streams in the filled/residential class.

In general, the measured substrate characteristics of the filled, filled/residential, and mined classes were not substantially different from the unmined class. However, there were specific stations within these EIS classes that were substantially different. Site photographs taken during the field work also illustrate these conclusions. It should be noted that many of the filled sites were established in first and second order streams in order to limit the potential stressors in the watershed to the valley fills. Our data indicate that the valley fills do not seem to be causing excessive sediment deposition in the first and second order streams that were sampled. Our results should not be extrapolated to reaches downstream in these watersheds or to higher order streams.

Table 17. Summary of Substrate Size and Composition Data Collected in the Spring of 2000 (mean and standard deviation)

Substrate Parameter: mean (standard dev.)	EIS Class			
	Unmined	Filled	Filled/residential	Mined
Mean Substrate Size Class	3.65 (0.31)	3.50 (0.45)	3.55 (0.84)	3.98 (0.30)
Calculated Mean Substrate Size (mm)	53 (coarse gravel)	38 (coarse gravel)	42 (coarse gravel)	109 (cobble)
% < or = to 2mm (% that is sand and fines)	16.9 (9.9)	20.7 (12.9)	29.7 (24.1)	8.0 (9.2)

7.0 ASSOCIATIONS BETWEEN BIOLOGICAL CONDITION OF STREAMS AND SELECTED PHYSICAL/CHEMICAL PARAMETERS

In the previous section, the physical and chemical conditions of the streams and stream classes were described using direct measurements of water quality, physical habitat, and substrate size and composition. We explored differences between the classes using the unmined class as a control group. In this section, we explore associations between the spring 2000 benthic metrics and median conductivity, total habitat scores, sediment deposition scores, and % sand and fines. These physical and chemical parameters were either substantially different between the EIS classes, appeared to be different at several individual sites, or they were measured at levels that could be considered limiting or harmful to aquatic life. We calculated the median conductivity over the study period at each of the sites and used that statistic to represent longer term conductivity values. We used the spring 2000 total habitat scores, sediment deposition scores, and % sand and fines estimates.

7.1 Correlation Analysis

Correlation analysis is used to determine the relationship between two variables without specifying a dependent and independent variable. That is, there is no causal relationship assumed.

We used Pearson Product Moment Correlation to explore associations between the benthic metrics and the physical and chemical parameters. The results of these tests are in shown in table 18. The correlation coefficient, r, quantifies the strength of the relationship between the variables. The values of r can vary between -1 and +1. A correlation coefficient near +1 indicates that there is a strong positive relationship between the two variables, with both always increasing together. A correlation coefficient near -1 indicates there is a strong negative relationship between the two variables, with one always decreasing as the other increases. A correlation coefficient of zero indicates no relationship between the two variables.

The P value is the probability of being wrong in concluding that there is a true association between the variables. The smaller the P value, the greater the probability that the variables are correlated. Traditionally, you can conclude there is a true association between the variables when $P < 0.05$.

Generally, all of the benthic metrics were associated positively or negatively, as expected to the potential stressors. The Stream Condition Index (SCI), Total Taxa, EPT, %EPT, Mayfly Taxa, and % Mayflies all decreased with increasing conductivity and increasing % sand and fines (increasing degradation). These same metrics all increased with increasing total habitat scores and increasing sediment deposition scores (decreasing degradation). The metrics HBI, % Two Dominant, and % Chironomidae all increased with increasing conductivity and % sand and fines. These metrics all decreased with increasing total habitat scores and sediment deposition scores.

Table 18 . Strength of Associations Between Benthic Metrics and Physical/Chemical Variables
Pearson Product Moment Correlation Matrix

r (correlation coefficient) p value	Median Conductivity (uS/cm)	Total Habitat Score	Sediment Deposition Score	% < or = to 2mm (% sand and fines)
WVSCI	-0.810 <0.01	0.459 <0.01	0.411 0.013	-0.296 0.079
Total Taxa	-0.699 <0.01	0.413 0.012	0.483 <0.01	-0.323 0.055
EPT	-0.783 <0.01	0.530 <0.01	0.601 <0.01	-0.378 0.02
%EPT	-0.753 <0.01	0.483 <0.01	0.433 <0.01	-0.369 0.03
HBI	0.672 <0.01	-0.360 0.031	-0.318 0.06	0.278 0.10
%2Dom	0.760 <0.01	-0.371 0.026	-0.384 0.02	0.194 0.26
%Chiro	0.511 <0.01	-0.219 0.200	-0.145 0.4	0.198 0.25
Mayfly Taxa	-0.812 <0.01	0.287 0.09	0.363 0.03	-0.183 0.29
% Mayflies	-0.780 <0.01	0.511 <0.01	0.429 <0.01	-0.320 0.06
Median Conductivity		-0.535 <0.01	-0.547 <0.01	0.348 0.04
Total Habitat Score			0.695 <0.01	-0.658 <0.01
Sediment Deposition Score				-0.756 <0.01
n = 36 for all pairs.				

The strengths of the associations varied ® values), as did the significance of the associations (P values). Generally, the strongest associations and the smallest P values were related to associations between the benthic metrics and the median conductivity. The associations between the benthic metrics and total habitat score and between the benthic metrics and the sediment deposition scores had lower correlation coefficients, and larger P values. The associations between the benthic metrics and the % sand and fines measurements had the lowest correlation coefficients and the highest P values. Many of the P values for this stressor were greater than the significance threshold of 0.05.

The Stream Condition Index (SCI) and the Mayfly Taxa metric were the benthic metrics most strongly correlated to median conductivity (r = -0.810 and r = -0.812) respectively. Many of the other metrics also had strong correlations.

It should be noted that we used a single habitat approach to sampling the benthic community; we only sampled riffles. The total habitat scores, sediment deposition scores and % sand and fines reflect habitat degradation in the entire reach, including pool habitat. Therefore, we would not necessarily expect strong correlations between benthic condition and habitat degradation measured throughout the reach since the benthic community was not sampled in all habitats.

It is also important to note that conductivity was negatively and quite strongly correlated to the total habitat score and the sediment deposition scores. Conductivity is often used as a general indicator of watershed disturbance. Our data indicate that watersheds with elevated conductivity are also likely to have degraded stream habitats. Disturbance in a watershed rarely impacts only water quality or only habitat.

Total habitat scores were strongly correlated with sediment deposition scores and % sand and fines. Sediment deposition scores were strongly correlated to % sand and fines. These parameters are all related: sediment deposition was one of the few habitat parameters that scored marginally at several sites and directly affects the total habitat score. The measurement of % sand and fines is simply a more quantitative estimate of sediment deposition.

7.2 Regression Analysis

Regression analysis involves one dependent and one independent variable. Regression analysis determines the relationship between two variables in cases in which the magnitude of one variable, the dependent variable or Y, is a function of the magnitude of the second variable, the independent variable or X. In order to determine how well some of these physical and chemical measures predict the benthic metrics (or in other words, stream condition), we used least squares simple linear regression. Table 19 shows the coefficient of determination values (r2) for each pair of variables. The coefficient of determination indicates how much of the variation in the observations can be explained by the regression equation. The largest value r2 can assume is 1, a result that occurs when all of the variation is explained by the regression, or all of the data points fall on the regression line.

Several of the variables failed either the normality test or the constant variance test of the linear regression and had to be transformed. The normality test requires that the source population is normally distributed around the regression line. Failure of the normality test can indicate the presence of outlying data points or an incorrect regression model (the model may be non linear). The constant variance test requires that the variance of the dependent variable (in our case the benthic metrics) in the source population is constant regardless of the value of the independent variable (in our case the physical and chemical measurements).

Table 19 . Least Squares Linear Regression Coefficients of Determination Non-Transformed Data				
r2 (coefficient of determination) values	**Median Conductivity (uS/cm)**	**Total Habitat Score**	**Sediment Deposition Score**	**% < or = to 2mm (% sand and fines)**
WVSCI	**0.656**	0.211	**0.169**	**0.088***
Total Taxa	**0.489**	**0.170**	0.233	0.104*
EPT	0.614	0.281	0.361	0.143
%EPT	0.567	0.233	**0.187**	0.136
HBI	0.451	0.130	0.101*	**0.077***
%2Dom	0.578	0.137	0.147	0.038*
%Chiro	**0.261**	0.048*	**0.021***	**0.039***
Mayfly Taxa	0.660	0.082*	0.132	0.033*
% Mayflies	0.608	0.261	0.184	**0.102***

n = 36 for all pairs.
r2 values in bold indicate that this data set failed either the normality test or the constant variance test and had to be transformed to use the linear regression model. See table 20.
*: r2 values marked with an asterisk had a P>0.05.

When the variables failed one or both of these tests, we used the transformation log (x) to transform some of the variables (SCI, Total Taxa, HBI, median conductivity, sediment deposition and total habitat scores). We used an arcsin square root transformation to transform the percentage metrics and measures (% Mayflies, % EPT, % Chironomidae, and % sand and fines). The percentage metrics and measures were first converted to proportions (values between 0 and 1) before being transformed. The coefficient of determination (r2) values for those pairs of variables which failed the assumptions of the test and had to be transformed are shown in table 20. For some of the variables, the standard transformations were not successful in resolving the normality and equal variance problems of the data sets (SCI vs. % sand and fines, Total Taxa vs. median conductivity, and Total Taxa vs. total habitat scores). The coefficients of determination for the transformed data sets are shown in table 20.

The non-transformed and transformed regressions for the Stream Condition Index (SCI) against conductivity are shown in figures 86 and 87. The non-transformed and transformed regressions for the SCI against sediment deposition scores are shown in figures 88 and 89. The non-transformed regressions for the SCI against total habitat scores and % sand and fines are shown in figures 90 and 91. The regression equations are provided in the figures. It should be noted that P was greater than 0.05 for the SCI vs. % sand and fines regression.

Table 20 . Least Squares Linear Regression Coefficients of Determination Transformed Data				
r2 (coefficient of determination) values	**Median Conductivity (uS/cm)**	**Total Habitat Score**	**Sediment Deposition Score**	**% < or = to 2mm (% sand and fines)**
WVSCI	0.560	N/A	0.199	**
Total Taxa	**	**	N/A	N/A
EPT	N/A	N/A	N/A	N/A
%EPT	N/A	N/A	0.222	N/A
HBI	N/A	N/A	N/A	0.070*
%2Dom	N/A	N/A	N/A	N/A
%Chiro	0.264	N/A	0.040*	0.036*
Mayfly Taxa	N/A	N/A	N/A	N/A
% Mayflies	N/A	N/A	N/A	0.124

n = 36 for all pairs.
*: r2 values marked with an asterisk had a P>0.05.
**: transformations did not solve normality or constant variance problems in data set.
N/A: data did not require transformations (see table 19).

Figure 86 and the regression equation for SCI and median conductivity suggest that in order for a site to score 70 or better (good or very good condition), the median conductivity must be 426 uS/cm or less. Figure 87 and the regression equation for SCI and transformed median conductivity suggest that in order for a site to score 70 or better (good or very good condition), the median conductivity must be 230 uS/cm or less. We believe the higher median conductivity concentration (426 uS/cm) is a more realistic threshold where adverse impacts to the biota may occur.

There were no apparent trends, or very weak trends between the SCI scores and sediment deposition scores, total habitat scores, and % of the substrate that was sand and fines (see figures 88, 89, 90 and 91). Sites with similar physical characteristics (i.e. similar sediment deposition scores, total habitat scores, or % sand and fines) had widely varying Stream Condition Index scores. Again, it is important to remember that we sampled the benthic community in the riffles only, and the parameter % sand and fines measures excess sediment deposition throughout the reach, including pools. Keeping in mind the implications of the use of the single habitat protocol to sample the benthic community, we still believe the data indicate most of the difference in the biological condition of these streams can be explained by water quality.

8.0 CUMULATIVE SITES AND SEDIMENT CONTROL STRUCTURE

This study considered three objectives. This study only provides limited data to address the second and third objectives. Our findings on these objectives are summarized below, but should be treated with caution since they are based on limited data.

Objective 2. Characterize conditions and describe any cumulative impacts that can be detected in streams downstream of multiple fills.

We used the WVDEP SCI scores to determine overall differences in biological condition upstream and downstream of four MTM/VF operations (table 18). A monitoring site was established as the upstream control, and a site was established as the downstream control. This was a difficult objective to explore. In three of the cases (Mud River, Spruce Fork, and Island Creek), there were potential stressors upstream of the upstream control site and in between the upstream and downstream control sites not related to the MTM/VF operations of interest. The upstream control sites in the Mud River and in Spruce Fork were impaired and the upstream control site in Cow Creek was not impaired. In one watershed (Clear Fork), this objective could not even be explored because several of the headwater streams in the watershed had been filled by the MTM/VF operation. The only substantial differences between the upstream and downstream sites was observed in Cow Creek (Island Creek Watershed). Conditions were much worse at the downstream site compared to the upstream site. The observed impairment could be caused by several stressors, including mining and residential land use.

Two of the watersheds are larger watersheds and the monitoring sites were located to compare conditions upstream and downstream of multiple fills. In the case of Mud River, site MT01 was established upstream of the MTM/VF operations and site MT23 was located downstream of these operations. Biological conditions degraded very slightly from upstream to downstream in the spring 1999 dataset. The upstream site on the Mud River could not be sampled in the summer of 1999 due to the drought. In the fall 1999, winter 2000, and spring 2000 datasets, the conditions improved from upstream to downstream. The difference observed in the fall 1999 dataset is the only difference that appears to be significant.

In the case of Spruce Fork, site MT40 was established upstream of the MTM/VF operations and site MT48 was established downstream of the operations. Biological conditions improved from upstream to downstream in the spring1999, summer 1999, fall 1999, and winter 2000 datasets. Conditions degraded from upstream to downstream in the spring 2000 dataset.. The difference observed in the spring 1999 dataset is the only difference that appears to be significant.

In both the Mud River and Spruce Fork watersheds, there are stressors other than mining in the reach between the sampling locations (residences and roads). In both watersheds, there are a few unmined tributaries that contribute flow to the watershed between the sampling locations.

Table 18. Summary of Biological Condition at Upstream and Downstream Control Sites			
Season	**SCI Score and Condition Class at Upstream Station**	**SCI Score and Condition Class at Downstream Station**	**Change in SCI Score from Upstream to Downstream**
Mud River Watershed			
	MT01	MT23	
Spring 1999	49 fair	45 fair	-4
Summer 1999	N/A	58 fair	N/A
Fall 1999	34 poor	68 fair	+34
Winter 2000	45 poor	53 fair	+8
Spring 2000	37 poor	42 fair	+5
Spruce Fork Watershed			
	MT40	MT48	
Spring 1999	38 poor	57 fair	+19
Summer 1999	49 fair	59 fair	+10
Fall 1999	53 fair	63 fair	+10
Winter 2000	29 poor	35 poor	+6
Spring 2000	43 poor	35 poor	-7

Table 18. Summary of Biological Condition at Upstream and Downstream Control Sites			
Season	**SCI Score and Condition Class at Upstream Station**	**SCI Score and Condition Class at Downstream Station**	**Change in SCI Score from Upstream to Downstream**
Twentymile Creek Watershed			
	MT91	MT86	
Spring 1999	73 good	81 good	+8
Summer 1999	67 fair	58 fair	-10
Fall 1999	77 good	77 good	no change
Winter 2000	78 good	74 good	-4
Spring 2000	85 very good	77 good	-8
Island Creek Watershed			
	MT52	MT55	
Spring 1999	82 very good	27 poor	-55
Summer 1999	63 fair	53 fair	-10
Fall 1999	71 good	34 poor	-37
Winter 2000	86 very good	23 very poor	-63
Spring 2000	88 very good	40 poor	-48
N/A: not applicable. The upstream site could not be sampled due to the drought.			

Two of the watersheds are smaller watersheds and sites were located to compare conditions upstream and downstream of the fills. In Rader Fork (Twentymile Creek watershed), site MT91 was established upstream of the operations and MT86 was established downstream of the operations. Biological conditions improved slightly from upstream to downstream in the spring of 1999. In the summer 1999, winter 2000 and spring 2000 datasets, conditions degraded slightly from upstream to downstream. There was no change in the stream condition index in the fall of 1999. None of these differences appear to be substantial. Rader Fork has no residences and there is mine drainage treatment on two of the fills influencing the stream.

In Cow Creek (Island Creek watershed), site MT52 was established upstream of the MTM/VF operations, and MT55 was established downstream of the operations. There is one very small fill upstream of site MT52, but it was built to face up the entrance to an underground mine and is not a typical valley fill. Biological conditions degraded from upstream to downstream in every season. Except for the difference observed in the summer 1999 dataset, these differences are substantial. There are several residences between the upstream and downstream sites in this reach. The impairment observed at site MT55 could be due to several stressors, including mining and residential land use.

In both Cow Creek and Rader Fork, there are no unmined tributaries that contribute flow to the watersheds between the sampling locations.

This objective could not be explored in the Clear Fork watershed as Toney Fork had several valley fills in its headwaters, and there was no "upstream" control.

Objective 3. Characterize conditions in sediment control structures (ditches) on MTM/VF operations.

We considered several sediment control structures as candidate monitoring sites. However, many of the sites were not reconstructed streams, but ponds or dry ditches filled with boulder-sized rip-rap. Only one sediment control structure was identified as having flowing water and could be sampled. Since only one such site was sampled, this study provides only limited information to characterize conditions in sediment control structures on MTM/VF operations.

Site MT24, located in a sediment control ditch on a surface mine, was more degraded than any site sampled in the study. The SCI score at this site was in the poor or very poor range over all five seasons. The entire drainage area of this site has been disturbed by mining, and the ditch does not represent natural stream habitat. This was also the only site in the study where we observed an exceedance of a water quality criterion. In the summer 1999 index period, we measured a dissolved oxygen concentration of 3.6 mg/l, which was less than the required minimum of 5 mg/l.

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APPENDIX 1. SITE ATTRIBUTES

Mud River Watershed

The headwaters of the Mud River rise in Boone County and flow in a northwesterly direction into Lincoln County. Most of the watershed lies in Lincoln County. The headwaters of the Mud River watershed do not lie in the primary mountaintop mining area as described by the West Virginia Geological and Economic Survey (figure 1). In this watershed, the area of concern is a strip of land approximately five miles wide that runs perpendicular to the watershed and straddles the Boone and Lincoln County line. The remaining downstream watershed is out of the area of concern.

From the headwaters to the northwestern boundary of the primary mountaintop mining area, the watershed lies in the Cumberland Mountains of the Central Appalachian Plateau (subecoregion 69d) (Woods et al 1999) (figure 2). Woods et al describe the physiography as being unglaciated, dissected hills and mountains with steep slopes and very narrow ridge tops. The geology is described as being Pennsylvania sandstone, siltstone, shale, and coal of the Pottsville Group and Allegheny Formation. The primary land use is forest with extensive coal mining, logging, and gas wells. Some livestock farms and scattered towns exist in the wider valleys. Most of the low-density residential land use is concentrated in the narrow valleys.

The remainder of the watershed lies in the Monongahela Transition Zone of the Western Allegheny Plateau (subecoregion 70b). The Monongahela Transition Zone is outside the primary area of mountaintop mining. However it is mined and there are fills associated with this mining. This area is unglaciated with more rounded hills, knobs, and ridges compared to the dissected hills and mountains with steep slopes and very narrow ridge tops found in the Central Appalachian Plateau (Woods et al 1999). Land slips do occur in the Monongahela Transition Zone. The geology is Permian and Pennsylvanian interbedded sandstone, shale, limestone and coal of the Monongahela Group and less typically the Waynesboro Formation. The primary land use is forest with some urban, suburban, and industrial activity in the valleys. There is also coal mining and general farming in this region.

Site MT01 was established on the Mud River (see figure 3). The county road and residences are the major disturbances in this part of the watershed. The Mud River watershed from its headwaters to site MT01 has seen very little mining activity. One small area of contour surface mining and some drift punch mining have taken place in Bearcamp Branch. Based on the USGS topographic map, the estimated area disturbed by mining is 16 acres, or about 0.8 percent of the watershed area upstream of site MT01. In addition, this mining occurred sometime prior to 1962. This site served as the upstream cumulative control for the Hobet MTM/VF complex. Site MT01 was classified as mined/residential. This site was not used in the final analysis of the classes since it has both historical mining and residences upstream.

Site MT02 was established on Rushpatch Branch upstream of all residences and a small farm. There is no history of mining in this watershed. There is evidence of logging and gas well development. This site was classified as unmined.

Site MT03 was established on Lukey Fork. This site was classified as an unmined site and logging is the only known disturbance that has occurred upstream of this site. This site was established well above the mouth of Lukey Fork because three valley fills were being constructed on the lowest three unnamed tributaries on the West side of Lukey Fork. In addition, a gas transmission line was relocated through the lower part of the watershed. These activities are related to the active Westridge Mine.

Site MT13 was established on the Spring Branch of Ballard Fork. Site MT13 was classified as unmined, and there is little evidence of human disturbance in the watershed, with the exception of historical logging activity.

The entire north side of Ballard Fork has been mined. There are ten fills on the north side of the watershed. The south side has not been mined. Site MT14 was established on Ballard Fork downstream of eight fills. Three permits were issued for this mining in 1985, 1988, and 1989.

Mountaintop mining has occurred on all of the ridges in the Stanley Fork watershed. There are a total of six fills within the Stanley Fork drainage. Both upper fills are large, with one fill on an unnamed tributary being about 1.3 miles long. Site MT15 was established on Stanley Fork downstream of all six fills. These mining permits were issued in 1988, 1989, 1991, 1992, and 1995.

A sediment control structure on top of the mining operation was also sampled (site MT24). This structure is associated with the 1.3 mile-long fill on the unnamed tributary to Stanley Fork. The structure is a series of wetland cells with flowing water in between the cells. This stream is located at the interface of the valley fill and overburden and is directly on the pavement of the lowest coal seam mined. This site was not used in the final analysis of the classes since it does not represent natural stream habitat. This site was classified as a sediment control structure.

Two valley fills are located in the Sugartree Branch watershed. One fill is small, but the other one is about one mile long. Site MT18 was established downstream of both of these fills. The mining permits were issued in 1992 and 1995.

Site MT23 was established on the Mud River downstream of the entire Hobet complex. Mining activity upstream includes both active and inactive surface mines and one active underground mine. This site was used as the cumulative downstream site for the Mud River Watershed. This site was established downstream of a total of 26 completed or under construction fills. This site was classified as filled/residential.

In the spring of 2000, another site was added in the Mud River Watershed. This site (MT106) was established on an unnamed tributary to Sugartree Branch and has historical surface mining but no valley fills in its watershed. This site was classified as mined.

Spruce Fork Watershed

The Spruce Fork watershed drains portions of Boone and Logan Counties. The stream flows in a northerly direction to the town of Madison where it joins Pond Fork to form the Little Coal River. About 85 to 90 percent of the watershed resides in the primary mountaintop mining region (figure 1). Only the northwest corner lies outside this region. The entire watershed lies within subecoregion 69d (Cumberland Mountains) (figure 2). The watershed has been the location of surface and underground mining activity for many years, and numerous subwatersheds have been disturbed.

Site MT39 was established on White Oak Branch (figure 4). White Oak Branch is a tributary with no surface mining, entering Spruce Fork from the east, not far downstream of the former Kelly Mine. This site was classified as unmined.

Site MT40 was established on Spruce Fork and served as the upstream control for the bulk of the Daltex MTM/VF operations. The watershed above this point is anything but pristine. Again, mining has been an ongoing activity for many years. Based on the information available (Cumulative Hydrologic Impact Analysis (CHIA) maps, topographic maps, and personnel knowledge), there are seven surface mine valley fills and three fills associated with refuse disposal located upstream of this sampling point. This site was classified as filled/residential.

Oldhouse Branch enters Spruce Fork in the town of Blair, from the east. Site MT42 was established on this tributary, well upstream of any residences. This tributary has no known history of surface mining and was classified as unmined.

Pigeonroost Branch is the next downstream tributary to Spruce Fork and enters the river from the east. Site MT45 was established on Pigeonroost Branch, well upstream of any residences. Some contour mining has occurred in the headwaters of this watershed. Based on permit information and topographic maps, this mining was done sometime between 1987 and 1989. Approximately 75 acres, or about 6.7 percent of the watershed, were disturbed. This site was classified as mined.

Site MT32 was established on Beech Creek downstream of five valley fills. Beech Creek enters Spruce Fork from the west. The watershed upstream of this site has been extensively mined over the years. Contour mining occurred prior to 1963 and has continued until the recent past. Mountaintop mining began in the late 1980s. Underground mining activity has also occurred in the watershed. This site was classified as filled.

MT34B was established on the Left Fork of Beech Creek. This watershed has also been extensively mined over the years by both underground and surface mining methods. There is evidence of contour mining prior to 1963 and continuing through 1989. It appears mountaintop mining began in the late 1980s and continued into 1999. Reclamation is still active in the watershed. Based on the information available, we estimate that greater than 80 percent of the watershed has been disturbed by mining activities. This site was classified as filled.

Site MT48 was established on Spruce Fork downstream of all the Daltex operations except for those activities on Rockhouse Creek. This site was used as a cumulative downstream site for Spruce Fork. To the best of our knowledge, we believe there are 22 valley fills upstream of this site. There are several small communities upstream of this site including Blair, Spruce Valley, Five Block, and Sharples. This site was classified as filled/residential.

Site MT25B was established on Rockhouse Creek below the sediment pond of a large valley fill. Over the years, greater than 90 percent of the watershed has been disturbed by mining activities. The valley floor was mined and some contour mining was done prior to 1963. The mountaintop mining permit for this watershed was issued in 1986. This mining impacted nearly the entire watershed above the sampling site, including the older mine workings. The mainstem of Rockhouse Creek has a low U-shaped fill. The side tributaries are more typical with the fills extending up to the pavement of the lowest coal seam mined. This site was classified as filled.

Clear Fork Watershed

Clear Fork flows in a northwesterly direction to its confluence with Marsh Fork where they form the Big Coal River near Whitesville. The entire watershed lies within Raleigh County. All but a tiny part of the watershed is within the primary mountaintop mining area and is within subecoregion 69d (Cumberland Mountains) (figures 1 and 2). The coal mining industry has been active in this watershed for many years. Both surface and underground mining have occurred in the past and continue today. Two subwatersheds, Sycamore Creek and Toney Fork, were sampled as part of this survey.

There are no unmined sites in Clear Fork. Site MT79 was established on Davis Fork, a tributary to Sycamore Creek (see figure 5). Site MT79 was initially classified as unmined, but further investigation revealed mining activity in the headwaters. This site was classified as mined.

Site MT78 was established on Raines Fork, also a tributary to Sycamore Creek. This watershed has been subjected to shoot and shove contour surface mining prior to 1965. The term "shoot and shove" applies to pre-law mining practices. This practice was primarily narrow bench contour mining where the spoil material was handled by shoving it over the side of the hill. There was little or no reclamation associated with this practice. Approximately 20 percent of this watershed has been disturbed in the past. There is evidence that the ridge tops have also been underground mined. This site was classified as mined.

Site MT81 was established on Sycamore Creek upstream of the confluence with Lem Fork. Part of the watershed upstream of this site has been contour mined using the old shoot and shove method. About 12 percent of the watershed was impacted by contour mining prior to 1965. Underground mining has also occurred in the ridge tops. A treatment plant for permit # U-3024 is located on the valley floor above MT81. The effluent from the mine is piped from the ridge top to the treatment plant. The plant treats the effluent with sodium hydroxide in order increase the pH and remove metals. On our field visits to the stream, we did not see a direct discharge to the stream. This site was classified as mined.

Site MT75 was established on Toney Fork downstream of five valley fills. Mountaintop mining occurred on both sides of the subwatershed upstream of this sampling point. There are numerous residences upstream of this point, which is unusual for a valley this size. The spring and summer samples were collected at this site. Site MT70 was later established downstream of site MT75 because of sampling and logistical constraints. The fall 1999, winter 2000 and spring 2000 samples were collected at MT70. MT70 was established about 0.6 miles downstream of MT75, downstream of one additional valley fill and some additional residences. Both sites were classified as filled/residential.

Site MT69 was established on Ewing Fork about 0.35 miles above its confluence with Toney Fork. Some contour mining was done in this watershed prior to 1965. About three percent of the watershed was disturbed by this activity. There are also indications that underground mining has occurred in the past. This site was not used in the analysis of the classes since it has both mining activity and a residence in its headwaters.

Site MT64 was established on Buffalo Fork. Some contour mining has occurred in this watershed prior to 1965 and prior to mountaintop mining. The mountaintop mining in this watershed was permitted in 1992 and 1993. There are five valley fills upstream of this site associated with these permits. Reclamation work is still under way on the south side of the watershed. There are no residences in the watershed above the sampling point. There is a small amount of pasture upstream of the sampled site. This site was classified as filled.

Site MT62 was established on Toney Fork and served as the cumulative downstream site for Toney Fork. MT62 was established downstream of the confluence of Toney Fork and Buffalo Fork, downstream of all eleven fills in the watershed and numerous residences. There is also a small amount of pasture in the Buffalo Fork drainage upstream of MT62. This site was classified as filled/residential.

Twentymile Creek Watershed

Twentymile Creek drains portions of four counties: Clay, Fayette, Kanawha, and Nicholas. It flows generally to the southwest where it joins the Gauley River at Belva, West Virginia. Except for a small area on the western edge of the watershed, it is within the primary mountaintop mining area, and it all lies within subecoregion 69d (Cumberland Mountains) (figures 1 and 2). The watershed upstream of Vaughn is uninhabited. Logging, mining, and gas wells are the primary activities upstream of Vaughn. There has been a limited amount of old mining in the watershed above Vaughn but the majority of the mining activity is more recent. Downstream of Vaughn there are numerous residences and some small communities.

Site MT95 was established on Neil Branch, a tributary of Twentymile Creek (figure 6). Neil Branch is located in the middle of the Twentymile Creek watershed. At the beginning of this study, we believed that the Neil Branch watershed was entirely forested with no recent logging or other activities. During the study we heard that some logging was occurring in Neil Branch, but we have not personally confirmed this. This site was classified as unmined.

Site MT91 was established on Rader Fork upstream of Neff Fork and was classified as an unmined site. There is an active haul road that runs adjacent to this stream. There is considerable coal truck traffic on this road which is a potential impact to the stream. Alex Energy Inc. has applied for a surface mine permit which would include the headwaters of Laurel Run, a tributary to Rader Fork.

Site MT87 was established on Neff Fork. There are three valley fills upstream of this sampling site, two in the headwaters of the mainstem and one on a tributary entering from the northeast. A mine drainage treatment plant is in place below the two mainstem fills and uses sodium hydroxide to increase the pH and remove metals. This site was classified as filled.

Site MT86 was established on Rader Fork about 500 feet upstream of its confluence with Twentymile Creek. This site was established downstream of both MT87 and MT91. This site was classified as filled.

Three sampling sites were established on Hughes Fork in the southern portion of Twentymile Creek watershed. This watershed is unique in that there is only one sediment pond for all fills in the watershed instead of one for each individual fill. The most upstream site (MT103) was established downstream of six completed fills. Site MT98, downstream of MT103, was established downstream of eight fills. One of the eight fills has not been completed. Site MT104 was established downstream of the large sediment pond which serves all eight fills. All three sites were classified as filled.

Island Creek Watershed

Island Creek flows in a generally northerly direction to Logan where it enters the Guyandotte River. The entire watershed is confined to Logan County. All but the northern part of the watershed lies in the primary mountaintop mining area and the entire watershed is located in subecoregion 69d (Cumberland Mountains) (figures 1 and 2). Extensive underground mining has occurred in the watershed for many years. As these reserves have been depleted and economics have changed, surface mining has taken on a bigger role in the watershed.

Two unmined sites (MT50 and MT51) were initially established in the Island Creek watershed (figure 7). They were both established on Cabin Branch. This watershed is leased to a hunting club and access is limited. There is a gas line and jeep trail running adjacent to the stream, and one gas well at the confluence of Cabin Branch and Jacks Fork. Site MT50 was established in the headwaters of the mainstem just upstream of the confluence with Jacks Fork and a gas well. MT51 was established further downstream and nearer the mouth of Cabin Branch. The watershed area at site MT51 is roughly twice as large as at site MT50.

In the spring of 2000, we added another unmined site in the Island Creek watershed. Site MT107 was established on Left Fork, upstream of the influence of the fills. We established this unmined site to provide a closer watershed reference site for the Cow Creek sites. Three valley fills have been proposed upstream of this site.

Site MT52 was established near the headwaters of Cow Creek, upstream of all fills associated with surface mining. There has been limited disturbance in the headwaters. Approximately 1.3 percent of the watershed was disturbed by an entry for an underground mine. The entry was faced up and a small fill with a sediment pond was created in the headwaters of Cow Creek. This site was classified as filled.

A single valley fill resides in the headwaters of Hall Fork of Left Fork. Site MT57B was initially established directly downstream of the sediment pond for the valley fill. Because of access and sampling constraints, the site was moved downstream nearer the mouth of Hall Fork in the fall of 1999. The new location was named site MT57. The spring and summer 1999 samples were collected at MT57B and all subsequent samples were collected at MT57. These sites were classified as filled.

Site MT60 was established on Left Fork downstream of both of the existing fills. These fills include the Hall Fork fill and a small fill in an unnamed tributary. Three additional fills are proposed for the headwaters of this stream. This site was classified as filled.

Site MT55 was established on Cow Creek below its confluence with Left Fork. This site also served as the cumulative downstream site for Cow Creek. There are four valley fills upstream of this site associated with mountaintop mining and one associated with the underground mine. There is also a small community located near the confluence of Cow Creek and Left Fork. The area disturbed by the surface mining in this watershed has different uses than the typical reclaimed area. There are residences, a log mill, small orchards and vineyards, beef cattle, and municipal sewage sludge disposal located on the surface mine. This site was classified as filled/residential.

Monitoring Site Attributes				
StationID	EIS Class	Basin	Order	Watershed Area (acres)
MT02	Unmined	Mud River	2	511
MT03	Unmined	Mud River	2	717
MT107	Unmined	Island Creek	1	382
MT13	Unmined	Mud River	1	335
MT39	Unmined	Spruce Fork	2	669
MT42	Unmined	Spruce Fork	1	447
MT50	Unmined	Island Creek	2	563
MT51	Unmined	Island Creek	2	1172
MT91	Unmined	Twentymile Creek	2	1302
MT95	Unmined	Twentymile Creek	2	968
MT103	Filled	Twentymile Creek	2	1027
MT104	Filled	Twentymile Creek	3	2455
MT14	Filled	Mud River	2	1527
MT15	Filled	Mud River	3	1114
MT18	Filled	Mud River	2	479
MT25B	Filled	Spruce Fork	2	997
MT32	Filled	Spruce Fork	3	2878
MT34B	Filled	Spruce Fork	3	1677
MT52	Filled	Island Creek	1	316
MT57	Filled	Island Creek	1	288
MT57B	Filled	Island Creek	1	125
MT60	Filled	Island Creek	2	790
MT64	Filled	Clear Fork	2	758
MT86	Filled	Twentymile Creek	3	2201
MT87	Filled	Twentymile Creek	2	752
MT98	Filled	Twentymile Creek	2	1208
MT23	Filled/Residences	Mud River	4	10618
MT40	Filled/Residences	Spruce Fork	4	11955
MT48	Filled/Residences	Spruce Fork	5	27742
MT55	Filled/Residences	Island Creek	3	3167
MT62	Filled/Residences	Clear Fork	3	3193
MT70	Filled/Residences	Clear Fork	2	1221
MT75	Filled/Residences	Clear Fork	3	876
MT106	Mined	Mud River	2	327

Monitoring Site Attributes				
StationID	**EIS Class**	**Basin**	**Order**	**Watershed Area (acres)**
MT45	Mined	Spruce Fork	3	1111
MT78	Mined	Clear Fork	2	524
MT79	Mined	Clear Fork	2	448
MT81	Mined	Clear Fork	3	1258
MT01	Mined/Residences	Mud River	3	1897
MT69	Mined/Residences	Clear Fork	2	708
MT24	Sediment Control Structure	Mud River	1	NA

Monitoring Site Attributes Continued		
StationID	**StreamName**	**Location**
MT02	Rushpatch Branch	approx. 500 ft. upstream of confluence with Mud River
MT03	Lukey Fork	approx 1 mile upstream of confluence with Mud River
MT107	Left Fork	approx. 100 m upstream of Hall Fork
MT13	Spring Branch of Ballard Fork	approx. 585 feet upstream of confluence with Ballard Fork
MT39	White Oak Branch	approx. 2000 ft. upstream of confluence with Spruce Fork
MT42	Oldhouse Branch	approx. 2400 ft upstream of confluence with Spruce Fork
MT50	Cabin Branch	approx. 650 ft upstream of confluence with Jack's Fork
MT51	Cabin Branch	approx. 1800 ft upstream of confluence with Copperas Mine Fork
MT91	Rader Fork	approx. 500 ft. upstream of confluence with Neff Fork
MT95	Neil Branch	approx. 500 ft. upstream of confluence with Twentymile Creek
MT103	Hughes Fork	approx. 2500 ft. upstream of confluence with Jim's Hollow
MT104	Hughes Fork	approx. 1.3 miles upstream of confluence with Bell's Fork. Downstream of pond on mainstem of Hughes Fork.
MT14	Ballard Fork	approx. 900 ft upstream of confluence with Mud River
MT15	Stanley Fork	approx. 700 ft upstream of confluence with Mud River
MT18	Sugartree Branch	approx. 2000 ft. upstream of confluence with Mud River
MT25B	Rockhouse Creek	approx. 1.2 miles upstream of confluence with Spruce Fork, downstream of pond
MT32	Beech Creek	approx 1.9 miles upstream of confluence with Spruce Fork
MT34B	Left Fork of Beech Creek	approx 900 ft upstream of confluence with Beech Creek, downstream of pond.
MT52	Cow Creek	approx 3 miles upstream of confluence with Left Fork
MT57	Hall Fork	approx. 500 ft upstream of Left Fork
MT57B	Hall Fork	approx. 3600 ft. upstream of Left Fork. Downstream of pond effluent
MT60	Left Fork	approx. 5000 ft. upstream of confluence with Cow Creek
MT64	Buffalo Fork	approx. 4900 ft. upstream of confluence with Toney Fork
MT86	Rader Fork	approx. 500 ft. upstream of confluence with Twentymile Creek
MT87	Neff Fork	approx. 800 ft. upstream of confluence with Rader Fork
MT98	Hughes Fork	approx. 200 ft. upstream of confluence with Jim's Hollow

Monitoring Site Attributes Continued		
StationID	**StreamName**	**Location**
MT23	Mud River	approx. 1300 ft. downstream of confluence with Connelly Branch, downstream of MTM
MT40	Spruce Fork	In Blair, directly upstream of confluence with White Trace Branch
MT48	Spruce Fork	approx 5100 ft downstream of confluence with Beech Creek
MT55	Cow Creek	approx. 1000 ft. downstream of confluence with Left Fork
MT62	Toney Fork	approx. 300 ft downstream of confluence with Buffalo Fork
MT70	Toney Fork	upstream of confluence with Ewing Fork
MT75	Toney Fork	approx 700 ft. downstream of Reeds Branch
MT106	NNT to Sugartree	upstream of confluence with Sugartree
MT45	Pigeonroost Branch	approx 4500 ft upstream of confluence with Spruce Fork
MT78	Raines Fork	approx. 400 ft. upstream of confluence with Sycamore Creek
MT79	Davis Fork	approx. 600 ft. upstream of confluence with Sycamore Creek
MT81	Sycamore Creek	approx. 500 ft. upstream of confluence with Lem Fork
MT01	Mud River	approx. 650 ft downstream of confluence with Rushpatch Branch
MT69	Ewing Fork	approx. 2000 ft. upstream of confluence withToney Fork
MT24	Stanley Fork	Stanley Fork Drainage, Sediment Control Structure

Monitoring Site Attributes Continued				
StationID	**Latitude**	**Longitude**	**USGS Quad**	**County**
MT02	38.050409	-81.932945	Mud	Boone
MT03	38.054968	-81.958674	Mud	Boone
MT107	37.710836	-82.037565	Barnabus	Logan
MT13	38.067288	-81.937647	Mud	Boone
MT39	37.862890	-81.803831	Amherstdale	Logan
MT42	37.873395	-81.822344	Amherstdale	Logan
MT50	37.844838	-82.103711	Holden	Logan
MT51	37.835209	-82.102368	Holden	Logan
MT91	38.344246	-80.958472	Gilboa	Nicholas
MT95	38.297422	-81.086116	Lockwood	Nicholas
MT103	38.249313	-81.258160	Mammoth	Kanawha
MT104	38.251236	-81.242886	Bentree	Kanawha
MT14	38.072155	-81.947080	Mud	Boone
MT15	38.084996	-81.956693	Mud	Boone
MT18	38.090552	-81.951047	Mud	Boone
MT25B	37.933609	-81.840678	Clothier	Logan
MT32	37.909185	-81.851805	Clothier	Logan
MT34B	37.905423	-81.846021	Clothier	Logan
MT52	37.709626	-82.064232	Barnabus	Logan
MT57	37.711111	-82.040286	Barnabus	Logan
MT57B	37.706352	-82.047282	Barnabus	Logan
MT60	37.715706	-82.040098	Barnabus	Logan
MT64	37.899344	-81.331196	Pax	Raleigh
MT86	38.352418	-80.958912	Gilboa	Nicholas
MT87	38.344591	-80.955857	Gilboa	Nicholas
MT98	38.250588	-81.251563	Mammoth	Kanawha
MT23	38.090968	-81.971783	Mud	Lincoln
MT40	37.874671	-81.832148	Clothier	Logan
MT48	37.932826	-81.823662	Clothier	Logan
MT55	37.726947	-82.029593	Barnabus	Logan
MT62	37.909472	-81.337667	Pax	Raleigh
MT70	37.910552	-81.325875	Pax	Raleigh
MT75	37.908626	-81.315588	Pax	Raleigh
MT106	38.094460	-81.951610	Mud	Boone
MT45	37.883155	-81.811142	Clothier	Logan

Monitoring Site Attributes Continued				
StationID	Latitude	Longitude	USGS Quad	County
MT78	37.919763	-81.407243	Dorothy	Raleigh
MT79	37.915166	-81.402750	Dorothy	Raleigh
MT81	37.907029	-81.403113	Dorothy	Raleigh
MT01	38.053931	-81.936138	Mud	Boone
MT69	37.913970	-81.324878	Pax	Raleigh
MT24	38.083213	-81.934656	Mud	Boone

APPENDIX 2. BENTHIC METRICS

Please contact the authors for electronic files of the taxonomic data**.**

Benthic Metrics - Spring 1999												
StationID	**EIS CLass**	**CollDate**	**BenSamp ID**	**Tot Taxa**	**EPT %**	**Chiro %**	**EPT Tax**	**2Dom %**	**HBI**	**WV SCI R100**	**Ephem %**	**Ephem Tax**
MT02	Unmined	04/19/99	04199902	25	40.71	47.27	13	56.83	4.97	70.40	19.67	5
MT03	Unmined	04/19/99	04199903	21	55.22	34.33	12	50.25	4.48	75.95	31.84	5
MT13	Unmined	04/20/99	04209901	21	70.15	19.39	13	38.01	3.15	86.27	31.89	5
MT39	Unmined	04/22/99	04229901	22	75.95	8.33	16	53.81	3.15	86.97	56.43	6
MT42	Unmined	04/22/99	04229907	21	80.92	9.25	13	29.48	3.46	94.88	38.73	5
MT50	Unmined	04/26/99	04269901	25	70.76	12.53	17	48.04	3.42	85.39	44.13	5
MT51	Unmined	04/26/99	04269902	16	84.86	6.25	11	57.93	2.99	81.35	45.67	5
MT91	Unmined	05/05/99	05059904	12	60.61	16.16	7	46.46	4.56	72.66	42.42	3
MT95	Unmined	05/05/99	05059905	22	65.59	30.00	17	44.71	4.36	84.28	26.18	5
MT14	Filled	04/20/99	04209902	13	53.04	36.82	6	80.07	4.37	54.92	4.73	2
MT15	Filled	04/20/99	04209903	9	22.02	63.30	4	77.98	5.89	39.15	0.00	0
MT18	Filled	04/20/99	04209908	10	32.46	25.22	3	59.42	5.19	50.09	0.00	0
MT25B	Filled	04/21/99	04219901	19	44.10	51.74	9	78.95	4.82	48.23	2.95	3
MT32	Filled	04/21/99	04219902	15	28.96	16.59	6	58.78	5.02	55.87	5.24	1
MT34B	Filled	04/21/99	04219903	13	57.61	26.63	4	77.72	4.27	56.43	0.00	0
MT52	Filled	04/26/99	04269903	20	67.35	7.22	11	47.77	3.96	81.84	25.09	4
MT57B	Filled	04/27/99	04279901	13	15.98	52.51	6	66.67	5.64	45.30	0.46	1
MT60	Filled	04/27/99	04279902	23	59.86	22.80	16	41.81	4.73	80.23	23.04	3
MT64	Filled	04/28/99	04289902	18	50.94	36.60	8	63.77	4.63	61.76	0.38	1
MT86	Filled	05/05/99	05059901	13	85.51	5.80	10	62.32	4.14	80.85	62.32	3
MT87	Filled	05/05/99	05059903	19	78.03	14.97	13	61.46	3.53	79.59	12.74	3
MT98	Filled	05/06/99	05069901	13	85.71	9.74	8	55.19	3.47	77.90	14.29	1
MT103	Filled	05/06/99	05069903	16	57.93	31.74	9	62.22	4.18	62.63	2.77	1
MT104	Filled	05/06/99	05069904	14	17.48	31.47	6	60.84	5.51	53.09	0.70	1
MT23	Filled/Reside ntial	04/20/99	04209909	14	20.96	42.78	7	69.97	5.71	44.91	0.00	0
MT40	Filled/Reside ntial	04/22/99	04229906	15	10.32	53.33	6	69.25	6.42	38.14	2.80	4
MT48	Filled/Reside ntial	04/22/99	04229909	18	20.77	28.27	9	60.77	5.55	57.08	14.81	4
MT55	Filled/Reside ntial	04/26/99	04269905	14	6.11	77.54	7	85.98	6.78	26.83	2.79	4
MT62	Filled/Reside ntial	04/28/99	04289901	13	14.75	48.20	6	71.15	5.85	41.33	0.66	2
MT75	Filled/Reside ntial	04/28/99	04289908	10	38.01	52.04	3	72.40	5.54	44.83	0.00	0
MT45	Mined	04/22/99	04229908	20	82.65	8.24	12	43.82	3.35	86.49	44.47	5
MT78	Mined	04/29/99	04299901	7	9.76	2.44	4	92.68	7.29	38.49	1.22	1
MT79	Mined	04/29/99	04299902	24	58.40	29.51	16	47.10	4.36	82.40	18.21	5
MT81	Mined	04/29/99	04299906	18	58.88	28.97	11	45.79	3.95	82.25	21.50	4
MT01	Mined/Resid ential	04/19/99	04199901	19	43.44	45.48	10	78.73	5.80	49.09	40.05	6

Benthic Metrics - Spring 1999												
StationID	**EIS CLass**	**CollDate**	**BenSamp ID**	**Tot Taxa**	**EPT %**	**Chiro %**	**EPT Tax**	**2Dom %**	**HBI**	**WV SCI R100**	**Ephem %**	**Ephem Tax**
MT69	Mined/Residential	04/28/99	04289903	16	46.80	36.70	10	63.30	4.66	62.61	2.89	2
MT24	Sediment Control Structure	04/20/99	04209910	9	1.07	75.73	1	83.20	6.96	23.48	0.00	0

Benthic Metrics - Summer 1999												
StationID	**EIS CLass**	**CollDate**	**BenSamp ID**	**Tot Taxa**	**EPT %**	**Chiro %**	**EPT Tax**	**2Dom %**	**HBI**	**WV SCI R100**	**Ephem %**	**Ephem Tax**
MT42	Unmined	7/29/99	07299912	16	48.26	5.81	9	37.79	4.28	78.59	19.77	3
MT91	Unmined	8/11/99	08119904	17	45.79	8.41	9	67.76	4.90	67.27	3.74	3.00
MT14	Filled	7/26/99	07269901	15	46.81	3.19	3	67.02	5.07	62.99	0.00	0
MT15	Filled	7/27/99	07279901	13	79.72	2.10	2	79.72	4.57	62.04	0.00	0
MT18	Filled	7/27/99	07279909	10	68.71	6.80	2	68.71	4.89	59.58	0.00	0
MT52	Filled	7/28/99	07289901	16	57.88	2.12	7	69.39	4.76	63.08	0.30	1
MT60	Filled	7/28/99	07289904	15	52.59	17.24	6	53.45	4.84	69.30	1.72	1
MT57B	Filled	7/28/99	07289905	18	29.85	23.13	6	44.78	5.08	65.91	0.75	1
MT34B	Filled	7/29/99	07299901	14	22.50	23.33	3	38.33	5.78	59.78	0.00	0
MT32	Filled	7/29/99	07299902	17	27.51	1.51	6	78.71	4.85	48.58	0.50	2
MT25B	Filled	7/29/99	07299903	15	66.10	20.34	6	81.60	5.48	54.72	0.00	0
MT64	Filled	8/10/99	08109909	13	56.92	9.88	5	69.57	4.61	60.70	0.00	0
MT86	Filled	8/11/99	08119901	11	60.19	25.93	4	70.37	4.89	58.45	0.00	0
MT87	Filled	8/11/99	08119903	13	77.23	11.88	5	82.18	4.97	64.16	0.00	0
MT98	Filled	8/12/99	08129901	10	68.82	9.41	5	68.82	4.86	61.98	2.35	1
MT103	Filled	8/12/99	08129903	11	56.35	24.31	6	53.04	3.99	65.77	1.10	1
MT104	Filled	8/12/99	08129904	12	33.33	37.76	4	68.37	5.84	46.82	0.68	1
MT23	Filled/Residential	7/27/99	07279910	13	33.12	27.27	5	56.49	5.15	57.90	0.00	0
MT48	Filled/Residential	7/27/99	07279912	16	51.41	11.44	6	72.01	4.66	59.38	1.94	3
MT40	Filled/Residential	7/27/99	07279914	14	28.29	40.44	6	64.54	5.86	48.92	4.78	3
MT55	Filled/Residential	7/28/99	07289902	12	21.89	17.60	4	59.66	5.54	52.76	3.86	3
MT62	Filled/Residential	8/10/99	08109901	15	18.89	39.56	4	73.22	5.74	41.02	0.11	1
MT75	Filled/Residential	8/10/99	08109911	11	30.88	50.53	3	80.00	5.94	40.13	0.00	0
MT45	Mined	7/29/99	07299911	19	62.91	5.09	8	42.18	3.95	80.77	21.09	3
MT79	Mined	8/9/99	08099901	18	65.29	14.12	9	62.35	4.67	70.41	0.00	0
MT69	Mined/Residential	8/10/99	08109910	15	61.86	8.47	4	67.37	5.20	61.73	0.00	0
MT24	Sediment Control Structure	7/27/99	07279911	12	1.52	82.68	3	89.39	6.98	21.57	0.43	1

Benthic Metrics - Fall 1999												
StationID	**EIS CLass**	**CollDate**	**BenSampID**	**Tot Tax**	**EPT %**	**Chiro %**	**EPT Tax**	**2Dom %**	**HBI**	**WV SCI R100**	**Ephem %**	**Ephem Tax**
MT91	Unmined	11/3/99	11039910	18	71.88	10.71	9	54.91	3.19	77.09	2.23	4
MT95	Unmined	11/3/99	11039911	4	18.18	0.00	2	90.91	6.67	36.64	0.00	0
MT18	Filled	10/25/99	10259902	17	35.65	35.22	5	55.22	5.19	58.37	0.00	0
MT15	Filled	10/26/99	10269901	12	64.08	12.68	4	50.70	3.53	70.28	0.00	0
MT14	Filled	10/26/99	10269909	7	88.11	7.49	3	83.26	1.87	62.56	0.00	0
MT25B	Filled	10/27/99	10279902	15	56.93	33.58	8	54.01	4.47	69.45	0.00	0
MT32	Filled	10/27/99	10279910	14	47.50	10.19	5	60.79	4.46	58.29	0.00	0
MT60	Filled	10/28/99	10289901	17	85.04	8.76	9	72.63	2.70	74.99	1.46	2
MT57	Filled	10/28/99	10289902	15	89.20	4.23	8	84.74	1.85	69.44	0.23	1
MT52	Filled	10/28/99	10289904	16	84.14	2.76	10	79.08	2.02	70.99	0.92	2
MT64	Filled	11/2/99	11029903	17	67.11	23.54	10	67.88	4.64	63.05	0.11	1
MT86	Filled	11/3/99	11039901	11	72.73	12.50	7	53.41	2.90	76.62	3.41	1
MT87	Filled	11/3/99	11039902	11	86.57	7.46	7	59.70	2.34	78.34	2.99	1
MT98	Filled	11/4/99	11049901	12	91.93	4.91	7	67.37	2.52	72.94	1.40	2
MT103	Filled	11/4/99	11049902	14	83.33	11.98	8	57.81	3.29	74.02	1.30	2
MT104	Filled	11/4/99	11049903	11	58.58	7.10	4	59.76	4.26	64.35	0.00	0
MT23	Filled/Residential	10/25/99	10259901	13	63.43	9.72	6	51.85	4.61	68.01	0.23	1
MT40	Filled/Residential	10/27/99	10279911	16	25.35	49.30	9	63.38	5.74	52.75	2.35	4
MT55	Filled/Residential	10/28/99	10289903	11	12.50	60.29	4	80.64	6.20	34.20	0.49	1
MT48	Filled/Residential	10/29/99	10299901	19	42.73	31.63	10	52.83	4.82	62.94	4.11	3
MT62	Filled/Residential	11/2/99	11029901	17	49.64	16.61	6	52.08	4.32	61.42	0.27	2
MT70	Filled/Residential	11/2/99	11029906	13	76.32	15.13	4	84.87	2.51	61.11	0.33	1
MT45	Mined	10/27/99	10279901	20	83.04	3.12	11	53.57	2.85	88.75	7.14	4
MT01	Mined/Residential	10/26/99	10269910	10	12.93	70.26	4	79.74	6.06	33.60	0.86	2
MT69	Mined/Residential	11/2/99	11029905	13	92.13	2.30	7	76.39	2.20	70.18	0.00	0
MT24	Sediment Control Structure	10/26/99	10269911	9	0.00	65.21	0	87.87	6.80	22.23	0.00	0

Benthic Metrics - Winter 2000												
StationID	**EIS CLass**	**CollDate**	**BenSamp ID**	**Tot Tax**	**EPT %**	**Chiro %**	**EPT Tax**	**2Dom %**	**HB I**	**WV SCI R100**	**Ephem %**	**Ephem Tax**
MT13	Unmined	1/25/00	01250010	15	81.82	4.55	10	38.64	2.07	91.33	40.91	3
MT03	Unmined	1/25/00	01250011	19	84.52	5.36	13	31.55	2.57	96.45	41.07	5
MT02	Unmined	1/25/00	01250018	23	58.64	24.07	14	41.36	3.67	86.87	27.16	5
MT42	Unmined	1/26/00	01260002	26	68.63	18.30	17	28.43	3.50	91.45	30.72	4
MT39	Unmined	1/26/00	01260003	18	55.21	32.42	10	57.76	4.29	67.80	12.97	4
MT51	Unmined	1/27/00	01270004	13	87.20	3.66	8	69.51	2.80	78.56	8.54	4
MT50	Unmined	1/31/00	01310001	21	81.46	11.92	14	36.42	3.02	95.87	28.48	4
MT91	Unmined	2/7/00	02070010	17	89.86	4.93	10	78.36	2.71	77.62	15.89	4
MT95	Unmined	2/8/00	02080005	19	67.57	15.32	13	30.63	4.06	90.44	30.63	4
MT18	Filled	1/24/00	01240002	13	9.88	56.89	3	85.03	6.39	32.14	0.00	0
MT15	Filled	1/25/00	01250001	8	12.22	63.33	4	81.11	6.32	34.90	0.00	0
MT14	Filled	1/25/00	01250009	12	61.54	21.15	4	44.23	3.92	69.89	0	0
MT25B	Filled	1/26/00	01260010	19	47.55	50.38	12	81.32	4.67	50.56	0.75	2
MT32	Filled	1/26/00	01260017	17	28.10	40.70	7	63.21	5.44	48.66	0.00	0
MT52	Filled	1/27/00	01270006	20	77.57	15.01	13	45.34	2.92	86.36	15.32	4
MT60	Filled	1/31/00	01310002	18	77.19	17.54	13	32.46	3.62	92.12	11.40	3
MT57	Filled	1/31/00	01310004	16	52.10	43.70	11	72.27	4.56	66.93	5.88	3
MT64	Filled	2/1/00	02010009	17	32.63	62.11	11	71.58	5.50	52.84	0.70	1
MT86	Filled	2/7/00	02070001	22	69.72	25.08	14	62.08	3.87	73.58	18.96	4
MT87	Filled	2/7/00	02070003	20	82.24	15.35	13	58.77	3.54	78.46	39.04	4
MT103	Filled	2/8/00	02080001	13	54.59	41.74	7	68.81	4.10	60.63	1.38	1
MT98	Filled	2/8/00	02080002	16	63.83	29.79	10	51.60	3.92	72.72	2.13	3
MT104	Filled	2/8/00	02080004	16	35.61	37.12	7	66.67	5.70	56.83	1.52	2
MT23	Filled/Residential	1/24/00	01240001	16	30.00	45.13	7	58.72	5.68	53.02	0.26	1
MT48	Filled/Residential	1/27/00	01270001	17	8.18	72.12	8	81.41	6.23	35.06	1.86	2
MT40	Filled/Residential	1/27/00	01270003	14	4.59	65.65	6	86.05	6.84	28.97	1.02	3
MT55	Filled/Residential	1/27/00	01270005	9	10.29	79.78	3	89.52	6.60	23.22	0.00	0
MT62	Filled/Residential	2/1/00	02010017	9	11.84	78.68	5	87.14	6.41	28.25	0.00	0
MT70	Filled/Residential	2/2/00	02020003	15	38.12	55.48	9	84.31	5.08	42.40	0.00	0
MT45	Mined	1/26/00	01260001	21	76.47	9.56	12	27.21	3.15	94.15	36.03	4
MT79	Mined	2/1/00	02010001	20	68.69	27.27	15	46.46	3.86	81.10	12.79	4

Benthic Metrics - Winter 2000												
StationID	**EIS CLass**	**CollDate**	**BenSamp ID**	**Tot Tax**	**EPT %**	**Chiro %**	**EPT Tax**	**2Dom %**	**HB I**	**WV SCI R100**	**Ephem %**	**Ephem Tax**
MT81	Mined	2/1/00	02010002	23	67.52	30.74	16	51.68	3.75	81.35	32.62	4
MT01	Mined/Residential	1/24/00	01240003	9	9.68	38.71	3	58.06	5.94	45.03	6.45	2
MT69	Mined/Residential	2/2/00	02020001	16	84.63	11.07	8	77.87	2.73	68.34	0.20	1
MT24	Sediment Cont. Struct.	1/25/00	01250019	13	0.14	89.07	1	93.75	6.96	16.17	0.14	1

Benthic Metrics - Spring 2000												
StationID	**EIS CLass**	**CollDate**	**BenSamp ID**	**Tot Taxa**	**EPT %**	**Chiro %**	**EPT Tax**	**2Dom %**	**HBI**	**WV SCI R100**	**Ephem %**	**Ephem Tax**
MT02	Unmined	04/17/00	04170001	19	59.72	23.61	11	40.28	4.01	85.24	19.44	4
MT03	Unmined	04/18/00	04180001	22	69.57	9.94	14	32.92	3.47	93.10	32.30	6
MT13	Unmined	04/18/00	04180010	20	69.28	7.19	12	38.56	3.73	90.35	44.44	5
MT51	Unmined	04/24/00	04240001	12	76.92	15.38	8	46.15	3.44	79.85	30.77	4
MT50	Unmined	04/24/00	04240002	15	76.25	12.50	9	37.50	3.52	86.42	46.25	5
MT39	Unmined	04/25/00	04250007	20	64.88	9.52	13	36.90	3.51	90.25	40.48	6
MT42	Unmined	04/25/00	04250008	20	68.10	18.10	13	35.34	4.02	90.18	38.79	4
MT107	Unmined	04/26/00	04260004	13	87.63	10.22	10	59.68	2.75	80.48	24.73	3
MT95	Unmined	05/03/00	05030005	18	58.25	29.13	12	44.66	4.59	82.54	24.27	4
MT91	Unmined	05/04/00	05040010	20	87.38	5.83	14	52.10	3.56	84.64	45.31	4
MT14	Filled	04/18/00	04180009	6	19.15	76.60	4	87.23	6.13	30.94	2.13	1
MT15	Filled	04/18/00	04180011	5	3.30	57.10	2	96.04	6.45	22.57	0.00	0
MT18	Filled	04/18/00	04180018	12	2.00	34.91	4	93.77	6.29	29.31	0.25	1
MT34B	Filled	04/25/00	04250010	11	7.20	12.49	3	88.47	5.88	37.60	0.00	0
MT25B	Filled	04/25/00	04250011	14	52.00	44.51	9	72.46	4.96	51.56	17.80	2
MT60	Filled	04/26/00	04260001	15	75.00	6.90	8	62.07	3.78	77.81	29.31	2
MT57	Filled	04/26/00	04260003	16	66.67	23.81	9	62.70	3.83	74.39	12.70	1
MT52	Filled	04/26/00	04260005	15	70.41	6.12	10	30.61	3.66	87.89	33.67	5
MT32	Filled	04/27/00	04270001	16	17.51	38.28	9	64.27	5.38	48.62	1.27	2
MT64	Filled	05/02/00	05020003	14	23.29	70.50	7	81.68	5.82	40.01	0.00	0
MT98	Filled	05/03/00	05030001	16	65.14	28.13	11	50.15	3.73	73.10	11.31	1
MT103	Filled	05/03/00	05030003	14	69.25	24.87	10	45.72	3.40	75.35	5.08	1
MT104	Filled	05/03/00	05030004	13	29.79	61.28	5	76.60	5.61	44.59	4.26	1
MT86	Filled	05/04/00	05040001	18	83.45	14.79	13	62.32	3.84	76.56	39.08	3
MT87	Filled	05/04/00	05040003	17	84.70	10.38	11	48.09	3.27	87.55	21.31	2
MT23	Filled/Residential	04/19/00	04190001	13	14.48	69.66	8	76.55	6.25	42.33	2.76	3
MT55	Filled/Residential	04/26/00	04260006	13	26.14	70.02	9	79.38	6.11	40.05	7.67	4
MT62	Filled/Residential	05/02/00	05020001	15	29.07	55.91	8	69.33	5.59	48.38	6.39	1
MT70	Filled/Residential	05/02/00	05020002	10	17.41	77.41	6	86.67	6.14	34.05	2.59	1
MT48	Filled/Residential	05/10/00	05100001	11	7.88	53.33	5	83.64	6.86	35.19	3.64	1
MT40	Filled/Residential	05/10/00	05100002	14	23.49	37.48	8	72.02	6.70	43.38	17.27	3
MT106	Mined	04/18/00	04180019	17	71.59	17.05	10	56.82	3.64	82.76	5.68	3
MT45	Mined	04/25/00	04250009	17	54.17	20.83	10	33.33	4.40	82.58	29.17	4
MT78	Mined	05/01/00	05010001	9	26.11	71.34	7	85.35	6.06	39.45	18.47	3

Benthic Metrics - Spring 2000												
StationID	**EIS CLass**	**CollDate**	**BenSamp ID**	**Tot Taxa**	**EPT %**	**Chiro %**	**EPT Tax**	**2Dom %**	**HBI**	**WV SCI R100**	**Ephem %**	**Ephem Tax**
MT79	Mined	05/01/00	05010002	17	65.28	31.94	13	52.78	4.07	80.07	8.33	3
MT81	Mined	05/01/00	05010003	21	54.17	39.35	14	54.17	4.65	77.00	35.19	5.00
MT01	Mined/Reside ntial	04/17/00	04170002	11	15.79	73.03	6	81.58	6.35	37.10	12.5	4.00
MT69	Mined/Reside ntial	05/02/00	05020005	16	43.71	39.94	9	68.87	4.77	59.34	2.52	1
MT24	Sediment Cont. Struct.	04/19/00	04190003	11	1.49	60.89	2	91.97	6.67	24.41	1.15	1

APPENDIX 3. FIELD CHEMICAL/PHYSICAL, PHYSICAL HABITAT AND SUBSTRATE SIZE DATA

Field Chemistry - Spring 1999						
StationID	**Basin**	**EIS Class**	**Collection Date**	**Conductivity (uS/cm)**	**pH (su)**	**Temperature ©**
MT02	Mud River	Unmined	4/19/99	60	6.76	14.7
MT03	Mud River	Unmined	4/19/99	49	6.80	15.5
MT13	Mud River	Unmined	4/20/99	51	7.73	9.8
MT39	Spruce Fork	Unmined	4/22/99	103	8.17	12.5
MT42	Spruce Fork	Unmined	4/22/99	74	8.29	16.5
MT50	Island Creek	Unmined	4/26/99	55	8.21	12.5
MT51	Island Creek	Unmined	4/26/99	71	8.02	13.8
MT91	Twentymile Creek	Unmined	5/5/99	73	6.57	13.3
MT95	Twentymile Creek	Unmined	5/5/99	38	6.91	13.1
MT103	Twentymile Creek	Filled	5/6/99	937	7.60	12.6
MT104	Twentymile Creek	Filled	5/6/99	731	7.95	14.2
MT14	Mud River	Filled	4/20/99	1201	8.10	11.8
MT15	Mud River	Filled	4/20/99	1970	8.33	14.6
MT18	Mud River	Filled	4/20/99	1854	8.20	14.8
MT25B	Spruce Fork	Filled	4/21/99	861	8.14	10.4
MT32	Spruce Fork	Filled	4/21/99	741	8.36	13.0
MT34B	Spruce Fork	Filled	4/21/99	2160	8.16	15.3
MT52	Island Creek	Filled	4/26/99	256	8.16	11.9
MT57B	Island Creek	Filled	4/27/99	669	8.43	14.1
MT60	Island Creek	Filled	4/27/99	303	8.45	14.0
MT64	Clear Fork	Filled	4/28/99	984	8.37	12.3
MT86	Twentymile Creek	Filled	5/5/99	233	6.82	11.2
MT87	Twentymile Creek	Filled	5/5/99	409	6.27	13.2
MT98	Twentymile Creek	Filled	5/6/99	873	7.47	12.6
MT23	Mud River	Filled & Residences	4/20/99	927	8.47	15.3
MT40	Spruce Fork	Filled & Residences	4/22/99	505	7.85	16.0
MT48	Spruce Fork	Filled & Residences	4/22/99	633	8.05	19.3
MT55	Island Creek	Filled & Residences	4/26/99	276	8.04	13.5
MT62	Clear Fork	Filled & Residences	4/28/99	734	8.53	12.1
MT75	Clear Fork	Filled & Residences	4/28/99	836	8.60	11.6
MT45	Spruce Fork	Mined	4/22/99	187	7.96	19.4
MT78	Clear Fork	Mined	4/29/99	118	8.65	8.9
MT79	Clear Fork	Mined	4/29/99	293	8.62	9.8
MT81	Clear Fork	Mined	4/29/99	90	8.51	9.2
MT01	Mud River	Mined & Residences	4/19/99	115	6.70	14.7
MT69	Clear Fork	Mined & Residences	4/28/99	729	8.54	12.0
MT24	Mud River	Sediment Control Structure	4/20/99	2510	8.36	15.1

Field Chemistry - Summer 1999							
StationID	**Basin**	**EIS CLass**	**Collection Date**	**Conductivity (uS/cm)**	**DO (mg/L)**	**pH (su)**	**Temperature ©**
MT42	Spruce Fork	Unmined	7/29/99	101	7.3	7.01	24.0
MT91	Twentymile Creek	Unmined	8/11/99	178	5.6	7.50	22.7
MT103	Twentymile Creek	Filled	8/12/99	1054	8.5	7.88	15.8
MT104	Twentymile Creek	Filled	8/12/99	892	8.3	8.15	22.5
MT14	Mud River	Filled	7/26/99	2300	7.0	8.22	25.4
MT15	Mud River	Filled	7/27/99	2500	7.9	7.94	22.8
MT18	Mud River	Filled	7/27/99	2270	7.7	7.64	23.7
MT25B	Spruce Fork	Filled	7/29/99	890	5.8	7.05	21.7
MT32	Spruce Fork	Filled	7/29/99	1178	6.7	8.11	22.8
MT34B	Spruce Fork	Filled	7/29/99	1461	5.9	7.43	23.5
MT52	Island Creek	Filled	7/28/99	850	7.0	7.74	21.5
MT57B	Island Creek	Filled	7/28/99	1293	6.5	7.65	23.8
MT60	Island Creek	Filled	7/28/99	595	6.8	7.88	20.9
MT64	Clear Fork	Filled	8/10/99	1148	9.1	7.97	16.6
MT86	Twentymile Creek	Filled	8/11/99	489	8.5	6.95	18.3
MT87	Twentymile Creek	Filled	8/11/99	530	8.0	7.27	19.2
MT98	Twentymile Creek	Filled	8/12/99	1025	8.4	8.09	16.3
MT23	Mud River	Filled & Residences	7/27/99	1532	7.3	7.95	26.1
MT40	Spruce Fork	Filled & Residences	7/27/99	1023	9.1	8.66	26.3
MT48	Spruce Fork	Filled & Residences	7/27/99	1067	8.7	8.44	25.0
MT55	Island Creek	Filled & Residences	7/28/99	688	7.4	8.13	21.5
MT62	Clear Fork	Filled & Residences	8/10/99	1141	9.8	8.17	15.3
MT75	Clear Fork	Filled & Residences	8/10/99	1292	8.6	8.31	19.0
MT45	Spruce Fork	Mined	7/29/99	264	8.7	7.42	21.9
MT79	Clear Fork	Mined	8/9/99	618	9.9	6.85	18.4
MT81	Clear Fork	Mined	8/9/99	274	7.4	7.08	18.2
MT69	Clear Fork	Mined & Residences	8/10/99	1165	8.5	7.84	17.5
MT24	Mud River	Sediment Control Structure	7/27/99	3490	3.6	7.51	26.9

Field Chemistry - Fall 1999							
StationID	**Basin**	**EIS CLass**	**Collection Date**	**Conductivity (uS/cm)**	**DO (mg/L)**	**pH (su)**	**Temperature ©**
MT91	Twentymile Creek	Unmined	11/3/99	133	11.7	7.36	8.5
MT95	Twentymile Creek	Unmined	11/3/99	49	11.3	7.65	9.1
MT103	Twentymile Creek	Filled	11/4/99	1060	11.4	7.00	4.8
MT104	Twentymile Creek	Filled	11/4/99	940	11.4	7.75	8.3
MT14	Mud River	Filled	10/26/99	1437	9.6	7.44	7.7
MT15	Mud River	Filled	10/26/99	1764	10.3	7.78	7.1
MT18	Mud River	Filled	10/25/99	1565	9.3	7.30	10.7
MT25B	Spruce Fork	Filled	10/27/99	785	8.4	7.60	11.1
MT32	Spruce Fork	Filled	10/27/99	1000	10.7	8.22	9.3
MT52	Island Creek	Filled	10/28/99	774	8.1	7.91	11.9
MT57	Island Creek	Filled	10/28/99	618	9.8	7.00	8.5
MT60	Island Creek	Filled	10/28/99	537	10.1	7.00	7.2
MT64	Clear Fork	Filled	11/2/99	1226	9.4	7.64	13.9
MT86	Twentymile Creek	Filled	11/2/99	304	11.6	7.13	8.4
MT87	Twentymile Creek	Filled	11/3/99	420	11.8	6.79	7.9
MT98	Twentymile Creek	Filled	11/4/99	986	11.8	7.53	4.8
MT23	Mud River	Filled & Residences	10/25/99	1087	9.3	7.16	10.5
MT40	Spruce Fork	Filled & Residences	10/27/99	826	9.8		15.1
MT48	Spruce Fork	Filled & Residences	10/29/99	1000	10.4	7.63	8.0
MT55	Island Creek	Filled & Residences	10/28/99	629	10.6	7.38	8.0
MT62	Clear Fork	Filled & Residences	11/2/99	1223	9.0	7.37	13.7
MT70	Clear Fork	Filled & Residences	11/2/99	1141	9.5	8.06	15.0
MT45	Spruce Fork	Mined	10/27/99	260	10.4	6.73	6.3
MT01	Mud River	Mined & Residences	10/26/99	277	9.0	8.13	12.1
MT69	Clear Fork	Mined & Residences	11/2/99	1247	8.9	8.03	15.8
MT24	Mud River	Sediment Control Structure	10/26/99	2140	9.0	7.99	9.8

Field Chemistry - Winter 2000							
StationID	Basin	EIS CLass	Collection Date	Conductivity (uS/cm)	DO (mg/L)	pH (su)	Temperature ©
MT02	Mud River	Unmined	1/25/00	66	13.3	7.51	0.9
MT03	Mud River	Unmined	1/25/00	57	13.3	7.78	0.9
MT13	Mud River	Unmined	1/25/00	58	13.1	9.35	0.4
MT39	Spruce Fork	Unmined	1/26/00	104	13.4	7.43	1.3
MT42	Spruce Fork	Unmined	1/26/00	77	13.1	6.47	1.7
MT50	Island Creek	Unmined	1/31/00	50	13.0	7.72	0.7
MT51	Island Creek	Unmined	1/27/00	72	15.2	6.33	0.4
MT91	Twentymile Creek	Unmined	2/7/00	132	12.1	8.40	5.0
MT95	Twentymile Creek	Unmined	2/8/00	40	13.3	7.92	3.0
MT103	Twentymile Creek	Filled	2/8/00	808	12.7	7.54	4.9
MT104	Twentymile Creek	Filled	2/8/00	689	13.1	8.43	3.7
MT14	Mud River	Filled	1/25/00	1050	14.0	7.89	0.9
MT15	Mud River	Filled	1/25/00	1740		7.27	-0.1
MT18	Mud River	Filled	1/24/00	1674	11.7	7.58	5.2
MT25B	Spruce Fork	Filled	1/26/00	827	13.8	7.83	5.2
MT32	Spruce Fork	Filled	1/26/00	762	14.5	8.33	2.0
MT52	Island Creek	Filled	1/27/00	585	14.1	7.40	1.4
MT57	Island Creek	Filled	1/31/00	504	12.0	7.94	3.2
MT60	Island Creek	Filled	1/31/00	434	12.5	7.92	2.5
MT64	Clear Fork	Filled	2/1/00	1016	12.4	7.72	1.4
MT86	Twentymile Creek	Filled	2/7/00	296	13.0	7.15	3.9
MT87	Twentymile Creek	Filled	2/7/00	535	12.4	7.37	3.0
MT98	Twentymile Creek	Filled	2/8/00	787	12.9	8.30	3.5
MT23	Mud River	Filled & Residences	1/24/00	940	13.0	7.68	2.6
MT40	Spruce Fork	Filled & Residences	1/27/00	727	15.1	8.51	2.4
MT48	Spruce Fork	Filled & Residences	1/27/00	859	14.1	7.89	1.8
MT55	Island Creek	Filled & Residences	1/27/00	573	16.1	6.98	0.4
MT62	Clear Fork	Filled & Residences	2/1/00	899	12.0	8.08	1.5
MT70	Clear Fork	Filled & Residences	2/2/00	1066	13.8		0.8
MT45	Spruce Fork	Mined	1/26/00	186	14.5	6.41	0.5
MT79	Clear Fork	Mined	2/1/00	449	12.3	7.60	1.8
MT81	Clear Fork	Mined	2/1/00	128	11.4	7.91	4.3
MT01	Mud River	Mined & Residences	1/24/00	258	13.8	8.12	0.8
MT69	Clear Fork	Mined & Residences	2/2/00	907	14.6	7.46	0.7
MT24	Mud River	Sediment Control Structure	1/25/00	2110	13.3	7.69	2.4

Field Chemistry - Spring 2000							
StationID	**Basin**	**EIS CLass**	**Collection Date**	**Conductivity (uS/cm)**	**DO (mg/L)**	**pH (su)**	**Temperature ©**
MT02	Mud River	Unmined	4/17/00	47	8.2	5.68	14.4
MT03	Mud River	Unmined	4/18/00	42	10.5	7.10	10.6
MT107	Island Creek	Unmined	4/26/00	133	8.1	7.47	12.0
MT13	Mud River	Unmined	4/18/00	44	10.0	7.50	10.1
MT39	Spruce Fork	Unmined	4/25/00	64	10.1	6.75	11.1
MT42	Spruce Fork	Unmined	4/25/00	47	10.9	7.25	10.5
MT50	Island Creek	Unmined	4/24/00	45	9.2	7.62	11.8
MT51	Island Creek	Unmined	4/24/00	56	9.1	7.82	11.5
MT91	Twentymile Creek	Unmined	5/4/00	67	8.9	6.38	14.2
MT95	Twentymile Creek	Unmined	5/3/00	39	9.5	7.49	15.2
MT103	Twentymile Creek	Filled	5/3/00	850	10.5	7.39	11.1
MT104	Twentymile Creek	Filled	5/3/00	650	10.6	7.90	13.7
MT14	Mud River	Filled	4/18/00	464	9.6	7.05	11.5
MT15	Mud River	Filled	4/18/00	1387	10.3	7.96	11.0
MT18	Mud River	Filled	4/18/00	976	10.0	7.69	13.3
MT25B	Spruce Fork	Filled	4/25/00	575	10.0	8.12	13.2
MT32	Spruce Fork	Filled	4/27/00	454	10.7	6.25	9.7
MT34B	Spruce Fork	Filled	4/25/00	1210	7.4	6.89	15.5
MT52	Island Creek	Filled	4/26/00	159	10.9	6.80	12.3
MT57	Island Creek	Filled	4/26/00	236	9.6	7.00	8.6
MT60	Island Creek	Filled	4/26/00	212	10.2	5.94	8.6
MT64	Clear Fork	Filled	5/2/00	1011	9.2	7.77	14.5
MT86	Twentymile Creek	Filled	5/4/00	242	9.1	6.04	13.3
MT87	Twentymile Creek	Filled	5/4/00	441	9.4	5.95	14.0
MT98	Twentymile Creek	Filled	5/3/00	773	10.7	7.85	10.6
MT23	Mud River	Filled & Residences	4/19/00	426	9.2	6.70	11.8
MT40	Spruce Fork	Filled & Residences	5/10/00	460	8.8	8.02	18.1
MT48	Spruce Fork	Filled & Residences	5/10/00	589	8.9	7.47	17.5
MT55	Island Creek	Filled & Residences	4/26/00	155	9.0	6.40	16.5
MT62	Clear Fork	Filled & Residences	5/2/00	751	9.4	6.97	13.0
MT70	Clear Fork	Filled & Residences	5/2/00	849	9.4	7.30	13.5
MT106	Mud River	Mined	4/18/00	152	10.5	8.54	10.5
MT45	Spruce Fork	Mined	4/25/00	94	10.7	7.39	10.8
MT78	Clear Fork	Mined	5/1/00	108	9.5	6.03	12.8
MT79	Clear Fork	Mined	5/1/00	466	9.4	6.26	14.6
MT81	Clear Fork	Mined	5/1/00	138	9.3	6.50	14.1
MT01	Mud River	Mined & Residences	4/17/00	76	8.0	6.36	16.7
MT69	Clear Fork	Mined & Residences	5/2/00	742	9.9	7.83	14.6

Field Chemistry - Spring 2000							
StationID	**Basin**	**EIS CLass**	**Collection Date**	**Conductivity (uS/cm)**	**DO (mg/L)**	**pH (su)**	**Temperature ©**
MT24	Mud River	Sediment Control Structure	4/19/00	1980	6.6	7.13	13.9

Rapid Habitat Assessment Data - Spring 2000

StationID	EIS CLass	Coll Date	Bank Sta-LB	Bank Sta-RB	Bank Veg P-LB	Bank Veg P-RB	Channel FlowS	Chan Alter	Embed-dedness	EpiFau Substrate	FreqOf Riffles	RipVeg ZW-LB	RipVeg ZW-RB	Sed Dep	Vel Depth	TotHab Score
MT02	Unmined	4/17/00	5	7	8	6	18	17	14	16	18	3	9	11	17	149
MT03	Unmined	4/18/00	8	9	8	8	18	18	13	11	18	9	9	14	10	153
MT107	Unmined	4/26/00	8	9	6	9	17	16	15	12	16	7	10	14	10	149
MT13	Unmined	4/18/00	9	9	9	8	18	18	16	16	18	9	9	14	10	163
MT39	Unmined	4/25/00	8	5	9	8	17	17	16	19	20	8	7	17	10	161
MT42	Unmined	4/25/00	8	9	7	9	17	16	16	19	19	7	9	15	14	165
MT50	Unmined	4/24/00	6	5	8	6	17	16	11	16	17	8	6	10	16	142
MT51	Unmined	4/24/00	7	4	8	2	19	15	12	18	18	8	1	13	16	141
MT91	Unmined	5/4/00	8	8	9	5	16	17	16	18	17	9	6	15	15	159
MT95	Unmined	5/3/00	6	7	9	9	18	17	19	18	18	10	8	19	10	168
MT103	Filled	5/3/00	9	7	7	4	17	18	14	16	18	7	7	13	10	147
MT104	Filled	5/3/00	9	8	8	8	17	15	17	11	16	9	9	13	10	150
MT14	Filled	4/18/00	6	8	9	7	18	17	12	14	17	9	7	8	16	148
MT15	Filled	4/18/00	8	8	7	9	18	15	14	11	17	9	7	6	16	145
MT18	Filled	4/18/00	8	5	9	4	18	13	12	17	17	9	3	10	13	138
MT25B	Filled	4/25/00	5	4	6	8	19	15	16	18	19	6	9	13	14	152
MT32	Filled	4/27/00	8	8	4	8	20	7	13	14	16	2	6	10	17	133
MT34B	Filled	4/25/00	8	9	6	9	18	10	9	11	16	4	9	7	10	126
MT52	Filled	4/26/00	8	5	9	5	18	12	12	17	18	9	4	13	16	146
MT57	Filled	4/26/00	8	9	9	9	19	16	12	17	18	9	9	10	10	155
MT60	Filled	4/25/00	8	9	7	9	17	16	16	17	19	6	9	14	10	157
MT64	Filled	5/2/00	8	5	5	7	17	18	16	18	18	3	6	16	10	147
MT86	Filled	5/4/00	9	7	10	7	16	18	17	19	18	10	6	16	17	170
MT87	Filled	5/4/00	7	6	7	9	18	14	17	17	17	6	9	17	10	154
MT98	Filled	5/3/00	9	9	8	8	18	16	18	17	18	9	2	17	10	159
MT23	Filled & Residences	4/19/00	8	7	6	4	18	14	14	12	16	3	2	5	16	125

Rapid Habitat Assessment Data - Spring 2000

StationID	EIS CLass	Coll Date	Bank Sta-LB	Bank Sta-RB	Bank Veg P-LB	Bank Veg P-RB	Channel FlowS	Chan Alter	Embed-dedness	EpiFau Substrate	FreqOf Riffles	RipVeg ZW-LB	RipVeg ZW-RB	Sed Dep	Vel Depth	TotHab Score
MT40	Filled & Residences	5/10/00	6	9	4	9	17	12	14	14	18	1	9	14	17	144
MT48	Filled & Residences	5/10/00	8	8	9	9	16	15	14	18	18	8	7	12	18	160
MT55	Filled & Residences	4/26/00	6	9	3	8	20	10	15	8	17	2	8	17	15	138
MT62	Filled & Residences	5/2/00	9	9	9	3	17	12	15	17	17	9	1	15	14	147
MT70	Filled & Residences	5/2/00	6	6	8	8	19	17	12	12	17	7	9	13	16	150
MT106	Mined	4/18/00	8	8	6	7	17	17	16	16	18	9	6	10	10	148
MT45	Mined	4/25/00	8	8	9	6	18	13	17	18	17	9	5	15	16	159
MT78	Mined	5/1/00	9	9	9	9	13	18	18	18	18	9	10	18	10	168
MT79	Mined	5/1/00	9	8	9	8	15	16	15	19	19	9	8	16	10	161
MT81	Mined	5/1/00	8	8	8	7	15	16	15	19	19	8	8	17	10	158
MT01	Mined & Residences	4/17/00	9	7	8	6	18	14	15	11	16	8	6	14	10	142
MT69	Mined & Residences	5/2/00	8	9	9	9	16	19	15	16	18	9	9	14	10	161
MT24	Sediment Control Structure	4/19/00	9	9	8	8	18	0		5	16	2	1		10	86

Substrate Size Characterization Data - Spring 2000				
Station ID	**EIS Class**	**Mean Size Class**	**Estimated Geometric Mean Diameter (mm)**	**% sand and fines (% < or = to 2mm)**
MT02	Unmined	3.41	31.1	27.3
MT03	Unmined	4.13	152.0	16.4
MT107	Unmined	3.91	93.9	12.7
MT13	Unmined	3.33	25.9	20.0
MT39	Unmined	3.96	105.9	5.5
MT42	Unmined	3.47	35.8	16.4
MT50	Unmined	3.7	59.1	16.4
MT51	Unmined	3.18	18.8	36.4
MT91	Unmined	3.55	42.0	16.4
MT95	Unmined	3.81	75.3	1.8
MT103	Filled	3.47	35.8	21.8
MT104	Filled	4.50	346.4	14.6
MT14	Filled	3.09	15.4	32.7
MT15	Filled	2.97	11.9	34.6
MT18	Filled	3.52	39.6	16.4
MT25B	Filled	3.91	93.9	1.8
MT32	Filled	2.70	6.5	47.3
MT34B	Filled	3.05	14.2	30.9
MT52	Filled	3.42	31.7	25.5
MT57	Filled	3.29	23.9	32.7
MT60	Filled	3.61	48.4	18.2
MT64	Filled	3.78	70.8	9.1
MT86	Filled	3.54	41.2	7.3
MT87	Filled	3.75	65.4	10.9
MT98	Filled	3.91	93.9	7.3
MT23	Filled & Residences	2.34	2.7	78.2
MT40	Filled & Residences	3.68	56.8	14.6
MT48	Filled & Residences	3.25	22.1	25.5
MT55	Filled & Residences	4.80	672.3	16.4
MT62	Filled & Residences	4.04	124.3	20.0
MT70	Filled & Residences	3.17	18.3	23.6
MT106	Mined	3.75	66.7	9.1
MT45	Mined	3.65	52.4	23.6
MT78	Mined	4.07	134.7	1.8
MT79	Mined	4.42	289.1	3.6
MT81	Mined	3.98	110.2	1.8
MT01	Mined & Residences	3.86	84.9	29.1
MT69	Mined & Residences	3.49	37.2	18.2

APPENDIX 4. MAPS AND FIGURES

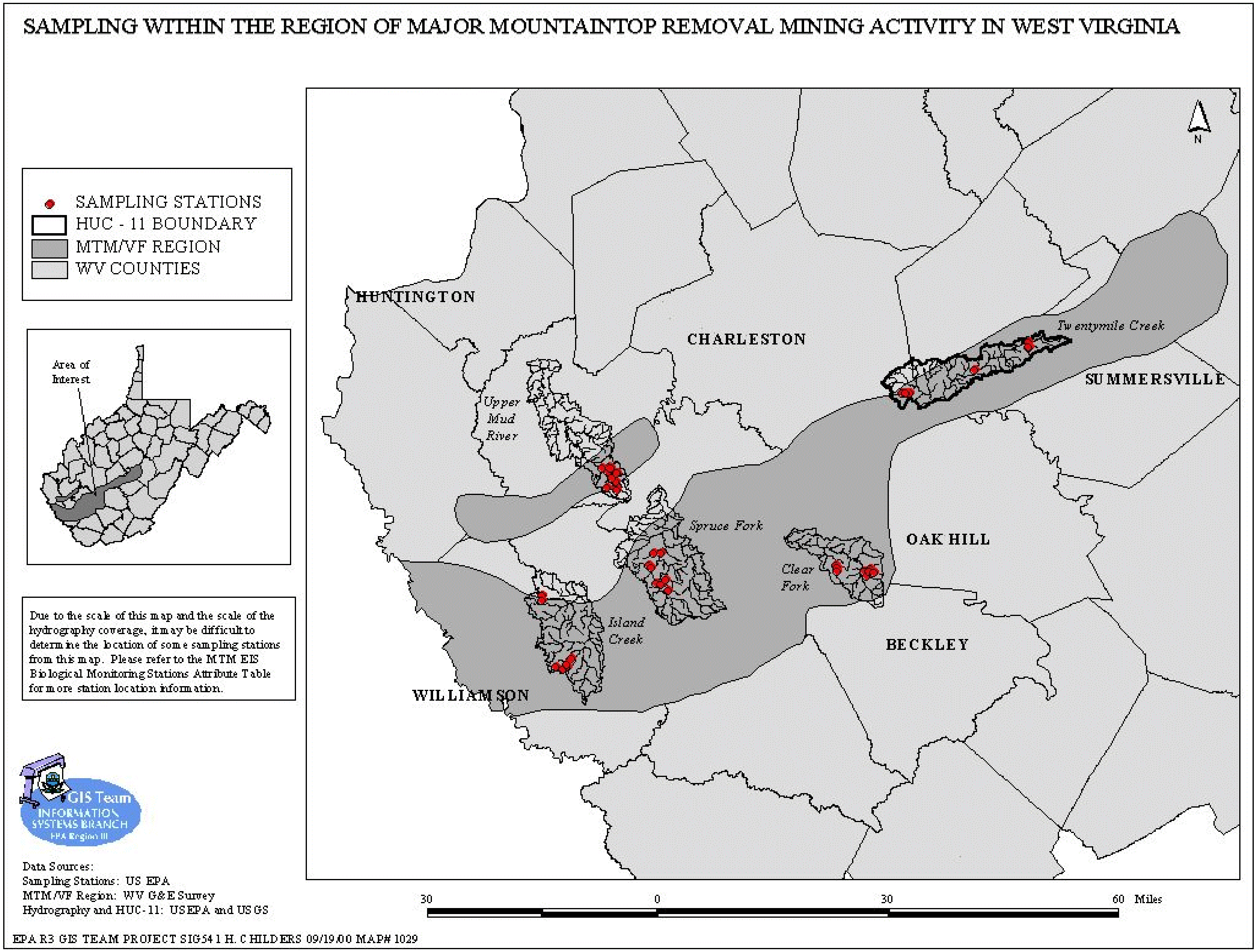


Figure 1. Sampling within the Region of Major Mountaintop Removal Mining Activity in West Virginia.

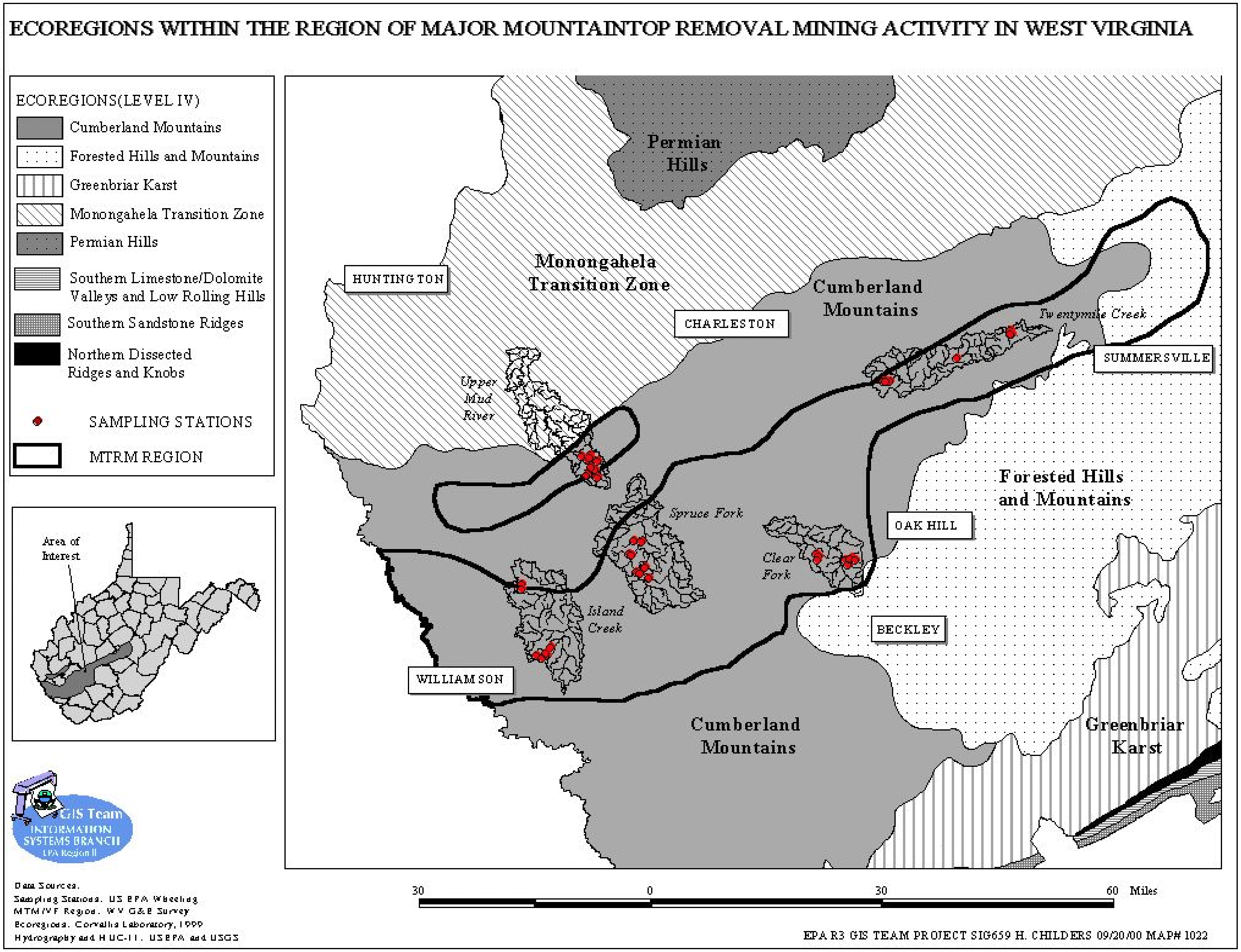


Figure 2. Ecoregions within the Region of Major Mountaintop Removal Mining Activity in West Virginia.

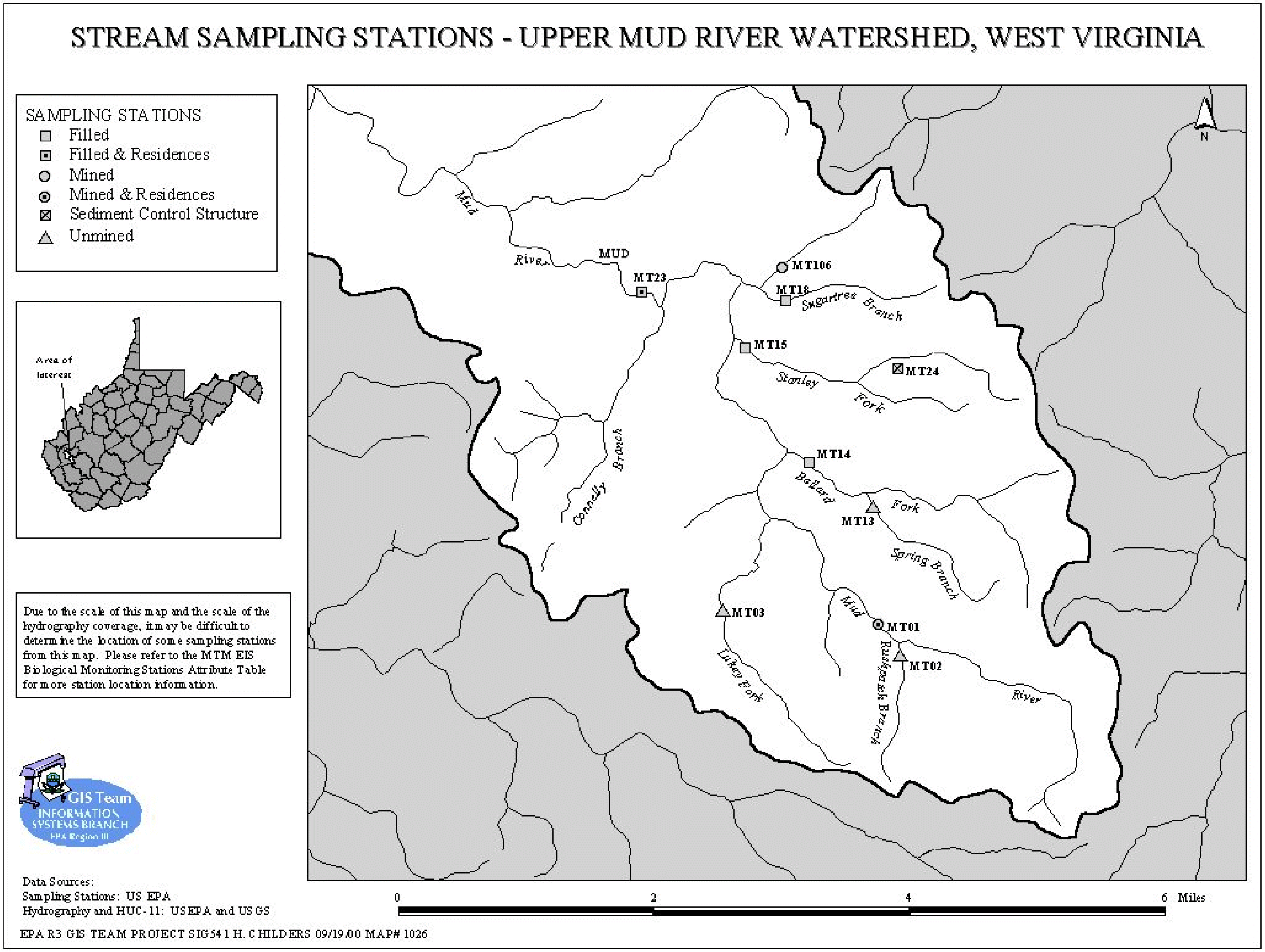


Figure 3. Stream Sampling Stations - Upper Mud River Watershed, West Virginia

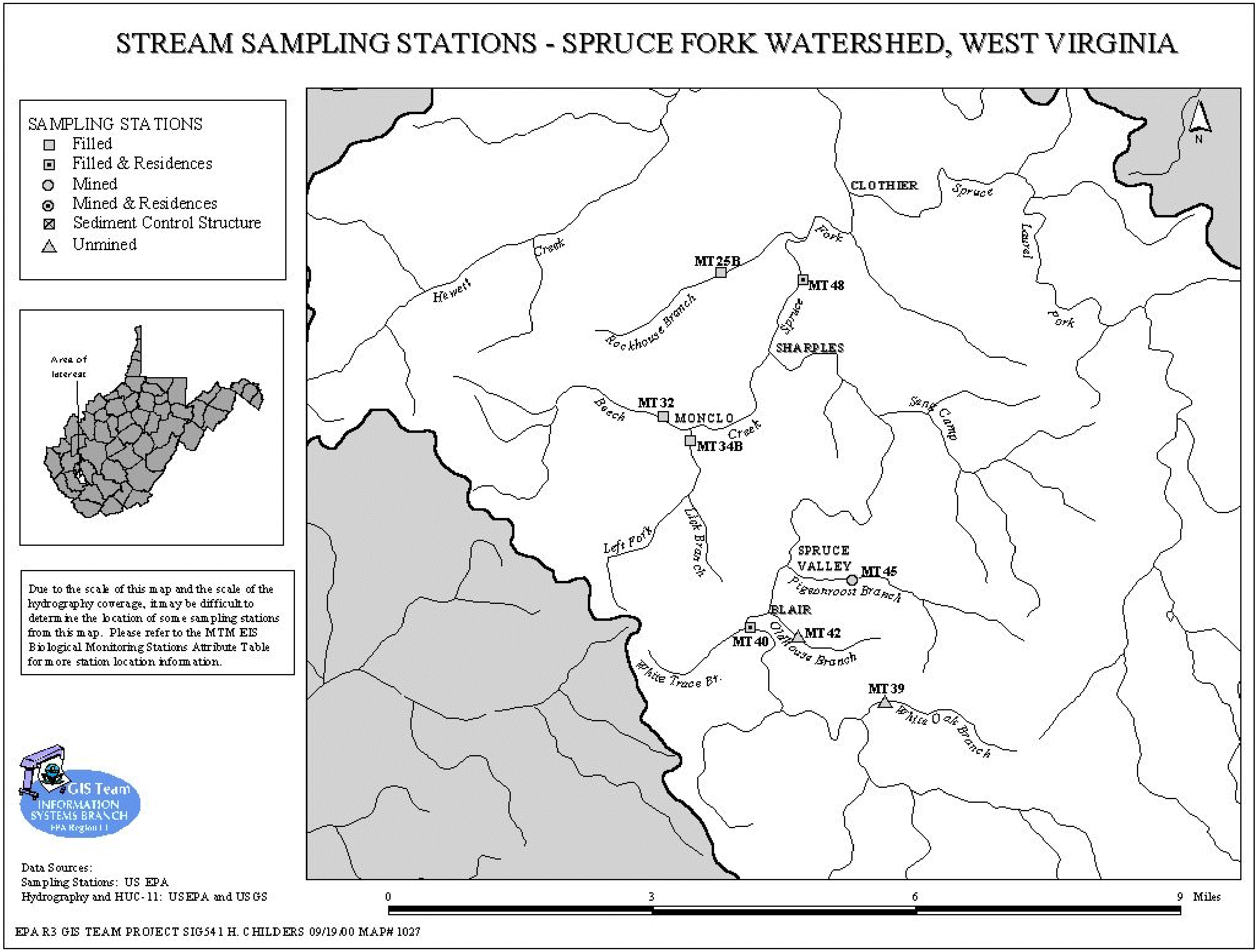


Figure 4. Stream Sampling Stations - Spruce Fork Watershed, West Virginia

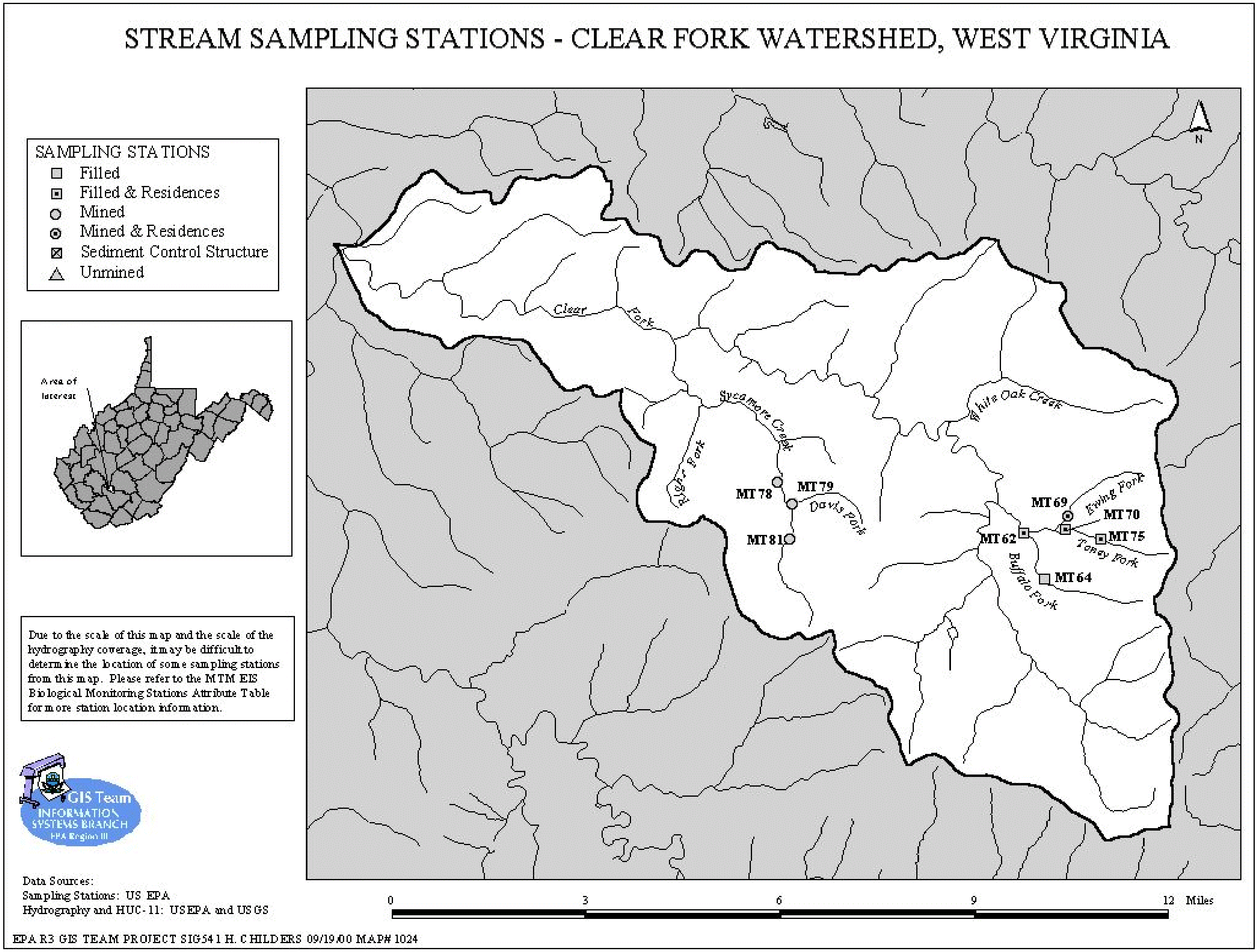


Figure 5. Stream Sampling Stations - Clear Fork Watershed, West Virginia

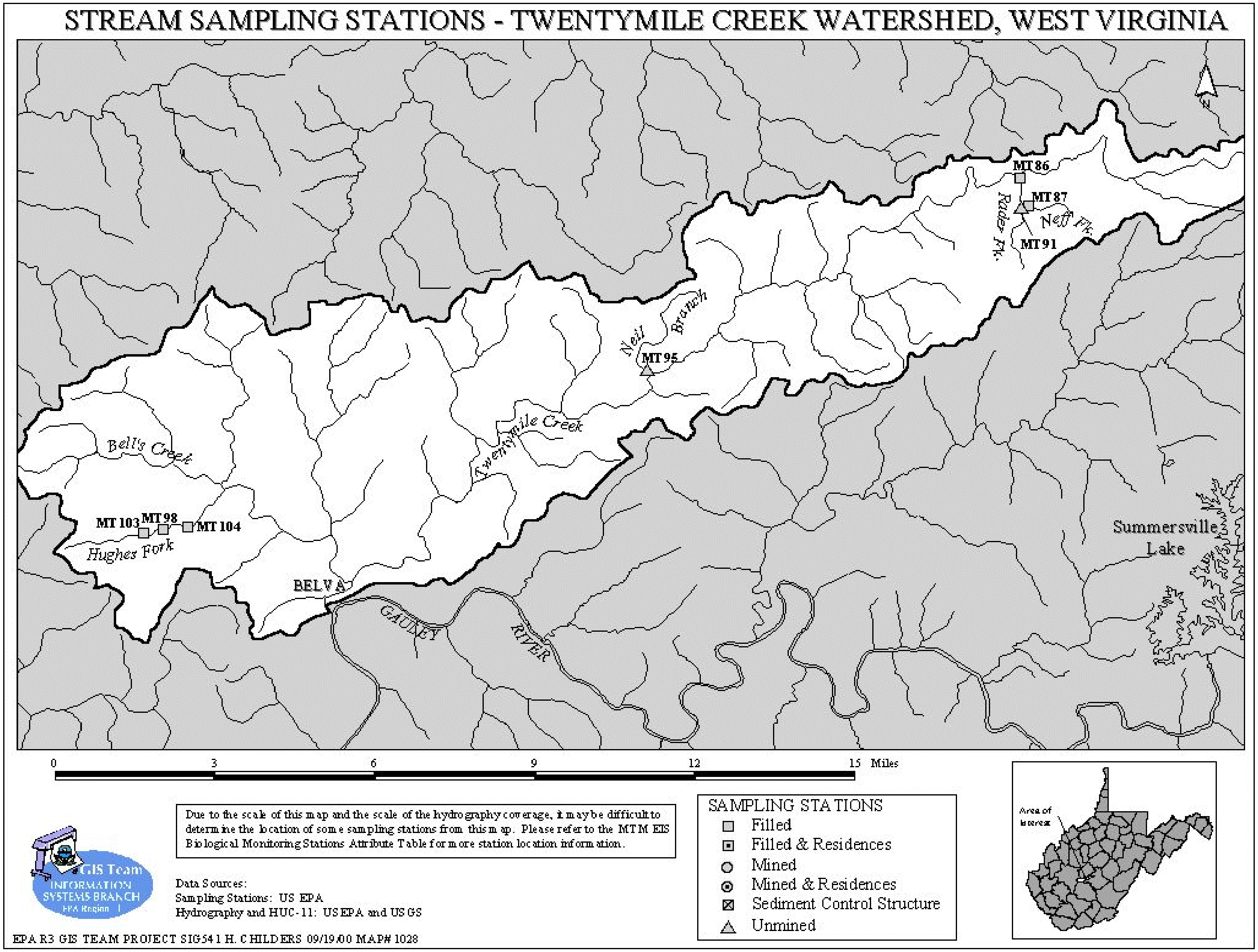


Figure 6. Stream Sampling Stations - Twentymile Creek Watershed, West Virginia

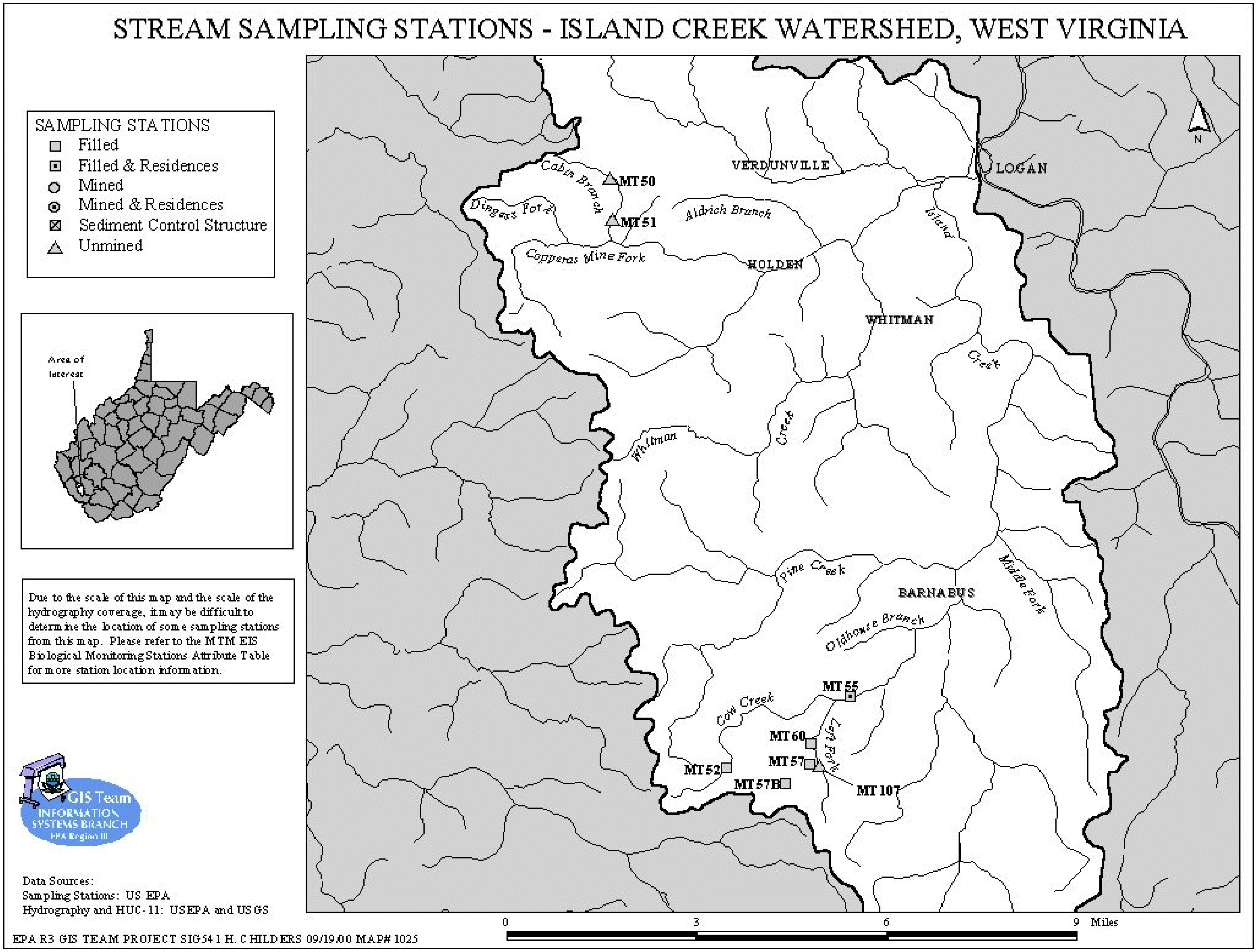


Figure 7. Stream Sampling Stations - Island Creek Watershed, West Virginia

Figure 8. Comparison of WV Stream Condition Index (SCI) Values
Spring 1999

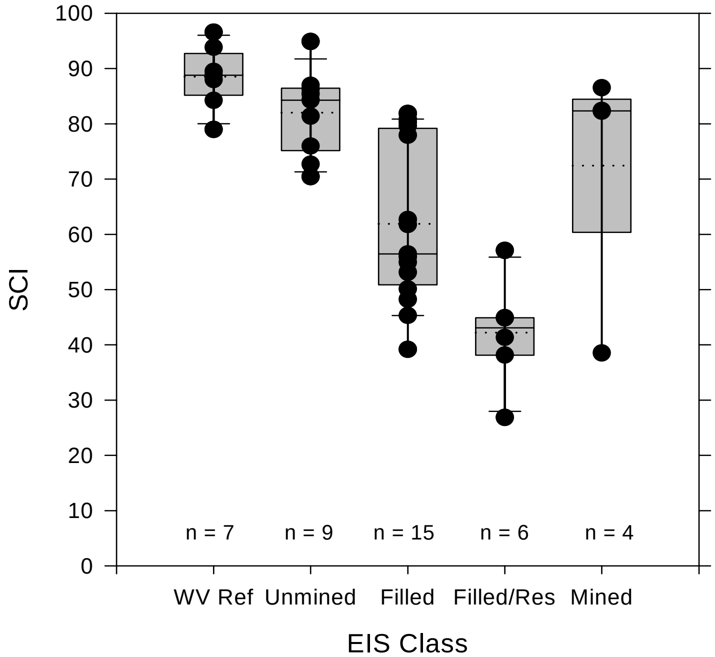


Figure 9. Comparison of Family-Level Total Taxa Values
Spring 1999

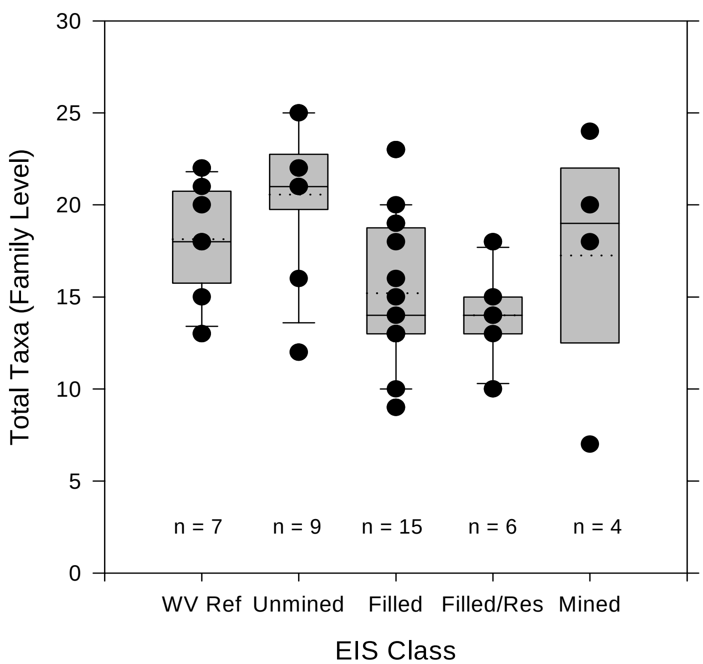


Figure 10. Comparison of Family-Level EPT Values
Spring 1999

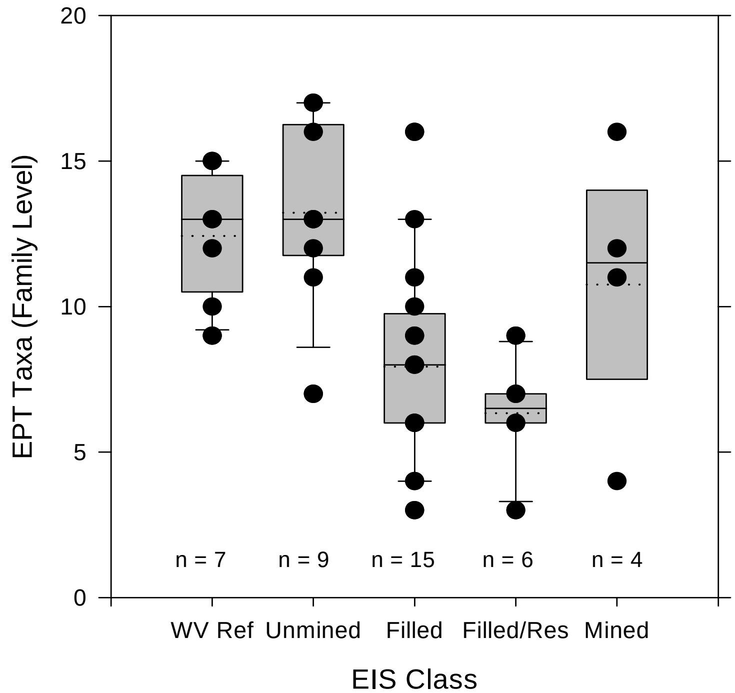


Figure 11. Comparison of %EPT Values
Spring 1999

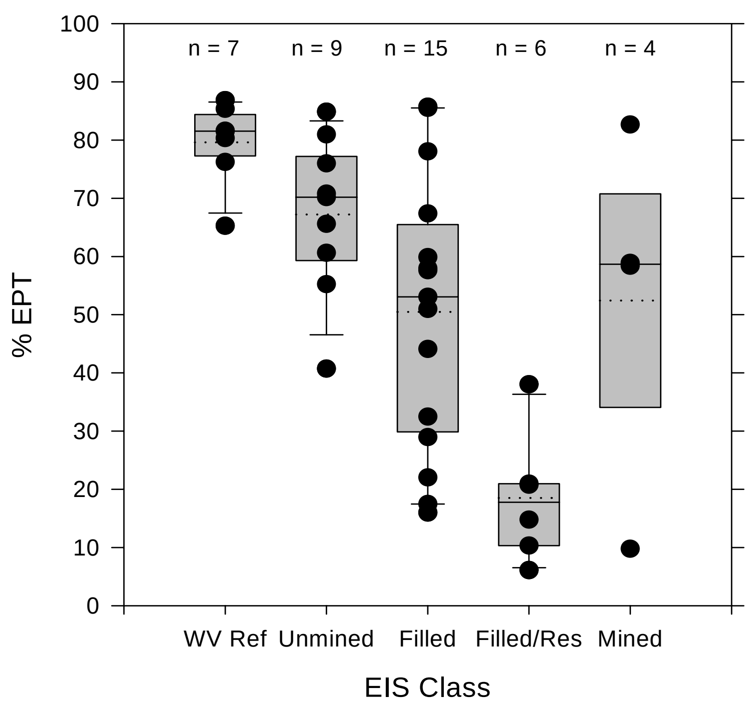


Figure 12. Comparison of HBI Values
Spring 1999

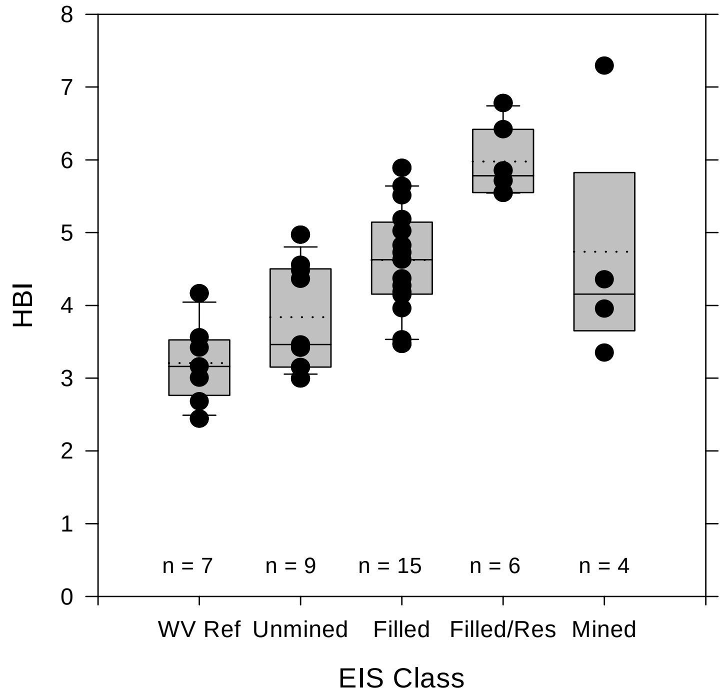


Figure 13. Comparison of % Two Dominant Familes Values
Spring 1999

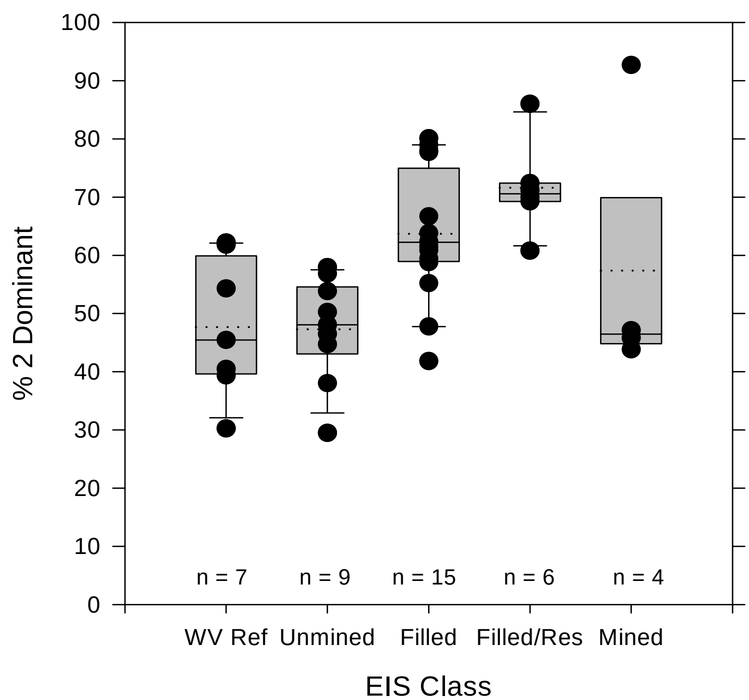


Figure 14. Comparison of Family-Level Mayfly Taxa Values
Spring 1999

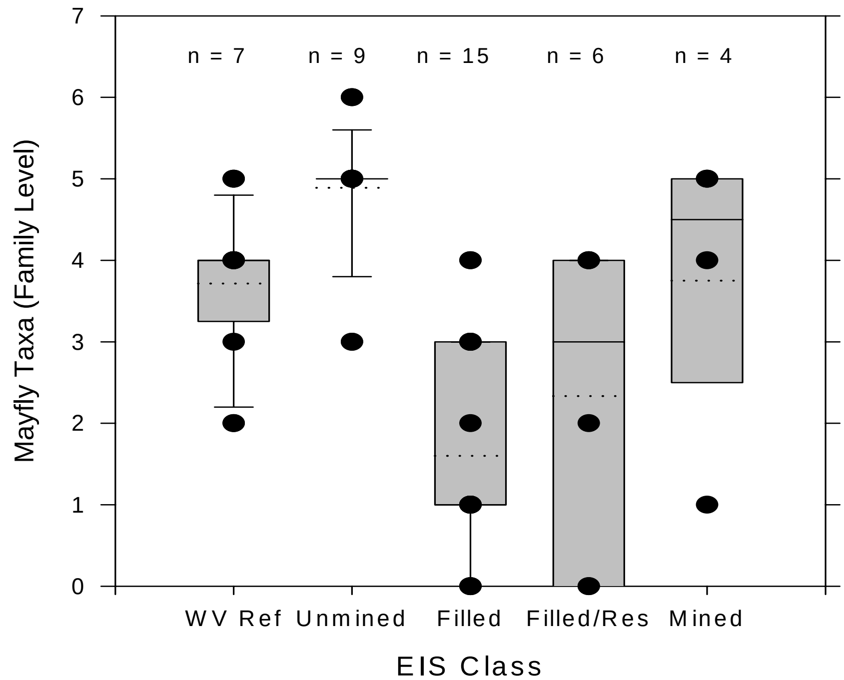


Figure 15. Comparison of % Mayfly Values
Spring 1999

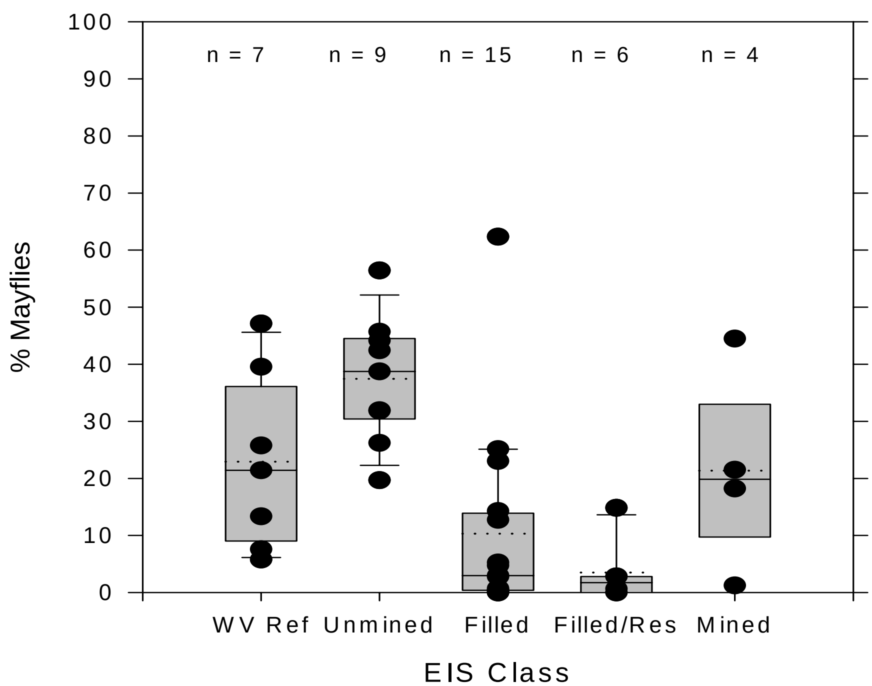


Figure 16. Comparison of % Chironomidae Values Spring 1999

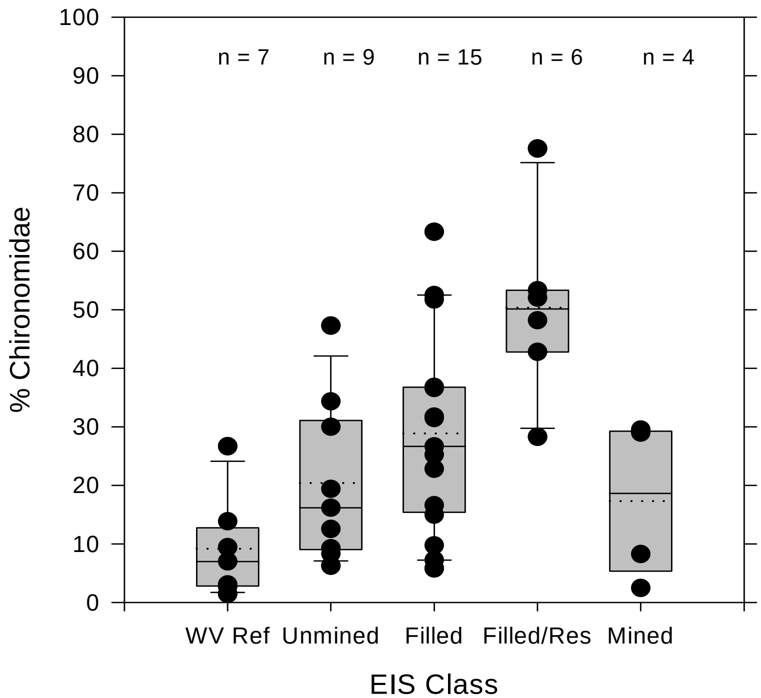


Figure 17. Comparison of WV Stream Condition Index Values
Summer 1999

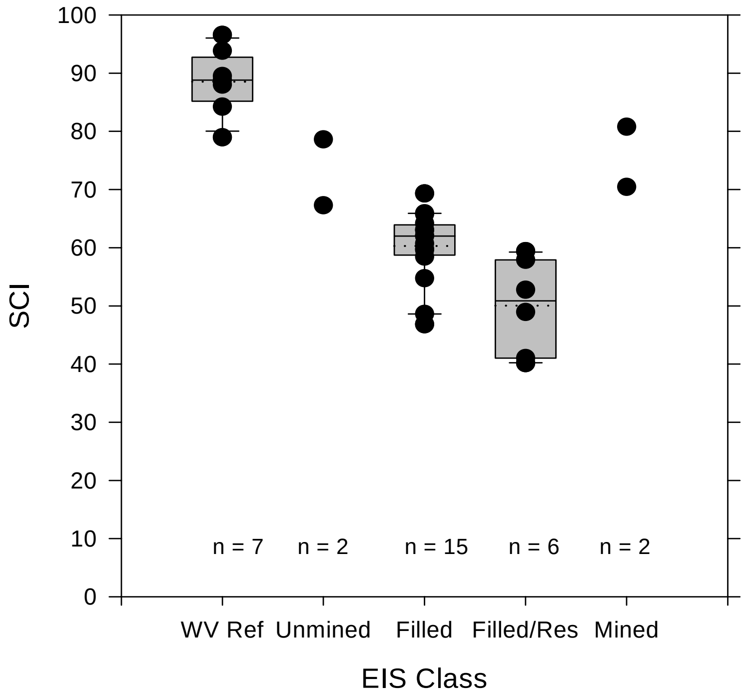


Figure 18. Comparison of Family-Level Total Taxa Vaues
Summer 1999

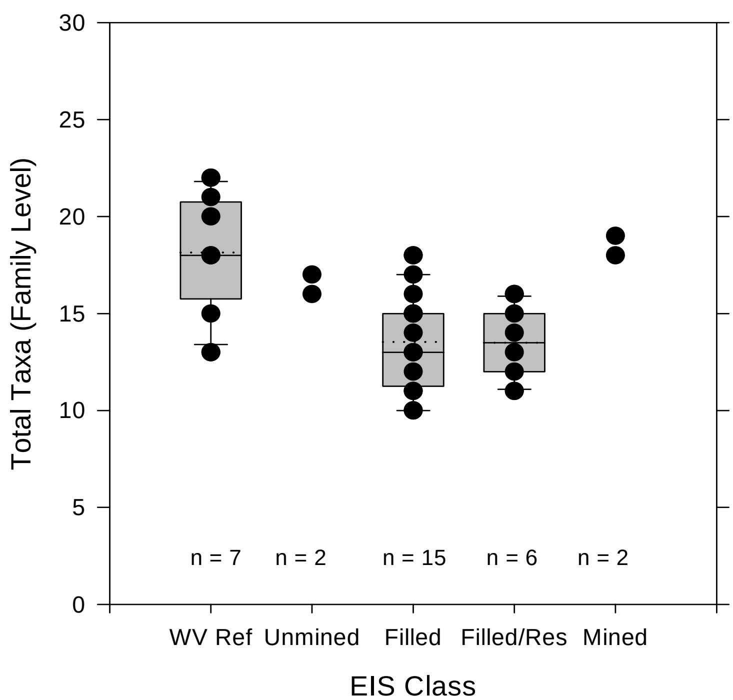


Figure 19. Comparison of Family-Level EPT Taxa Values
Summer 1999

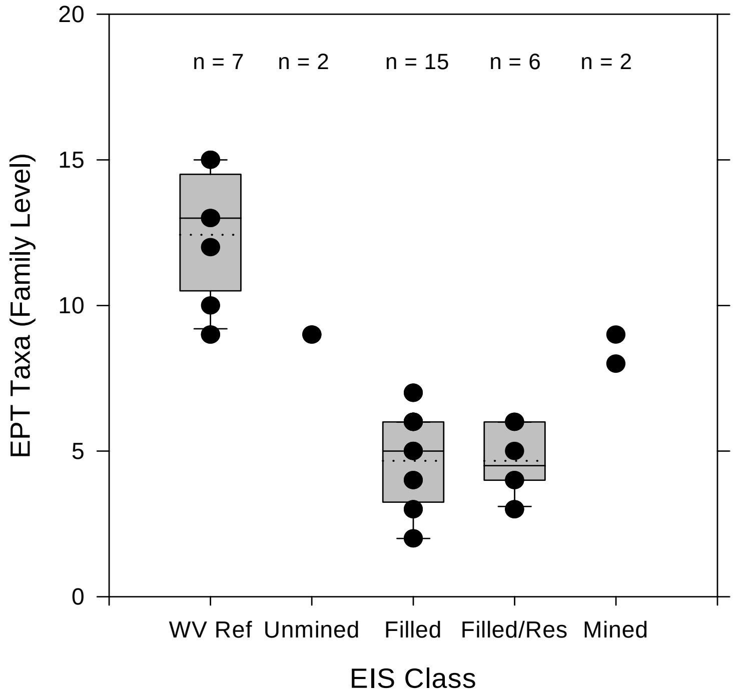


Figure 20. Comparison of % EPT Values
Summer 1999

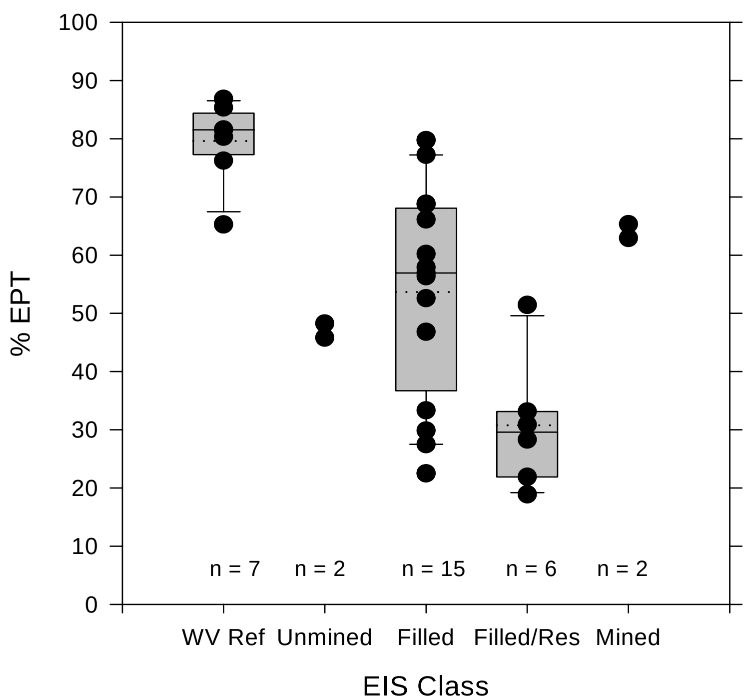


Figure 21. Comparison of HBI Values
Summer 1999

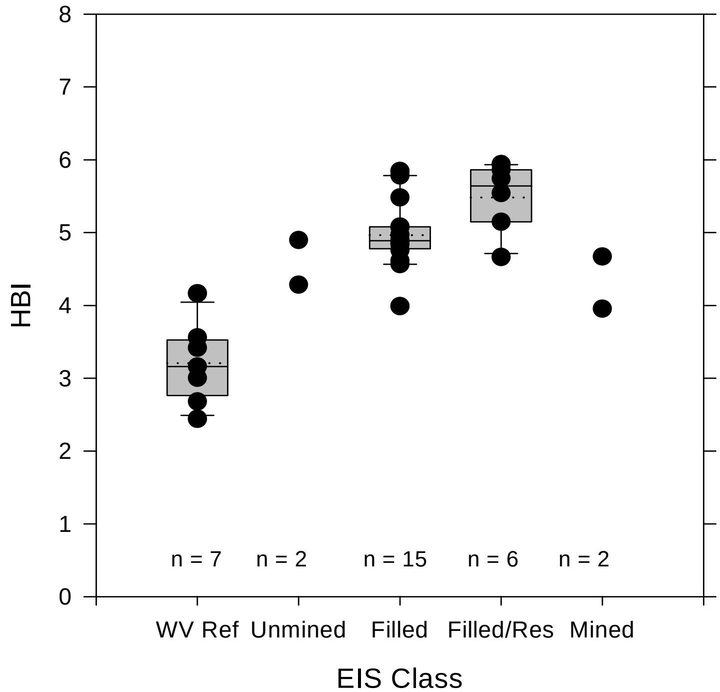


Figure 22. Comparison of % Two Dominant Families Values
Summer 1999

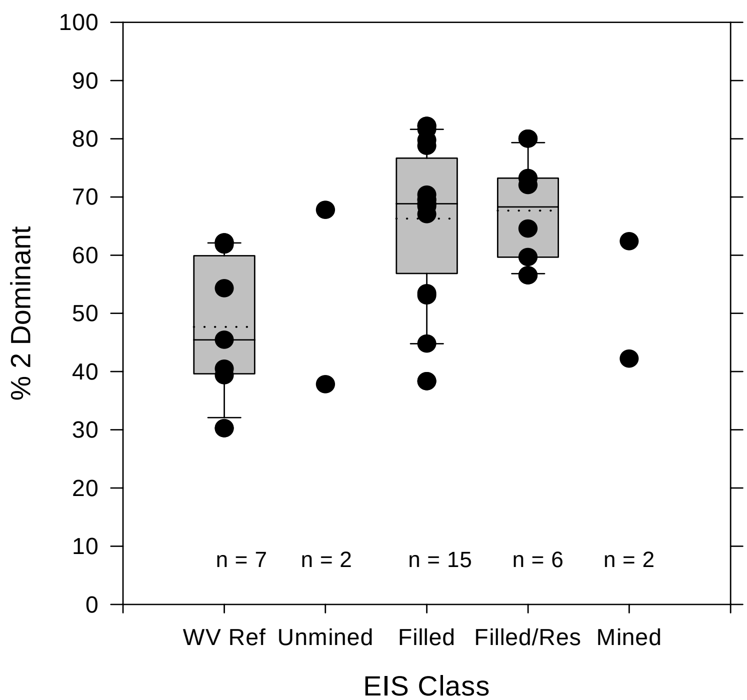


Figure 23. Comparison of Family-Level Mayfly Taxa Values
Summer 1999

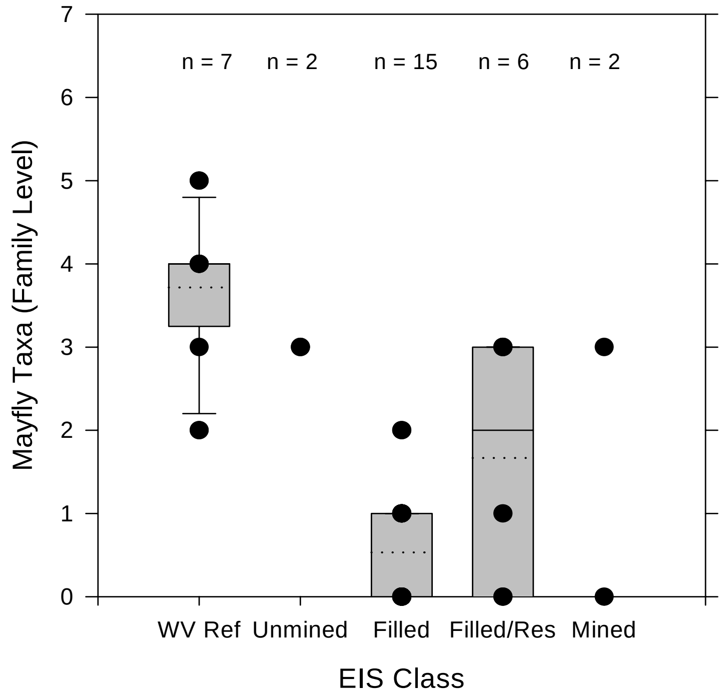


Figure 24. Comparison of % Mayfly Values
Summer 1999

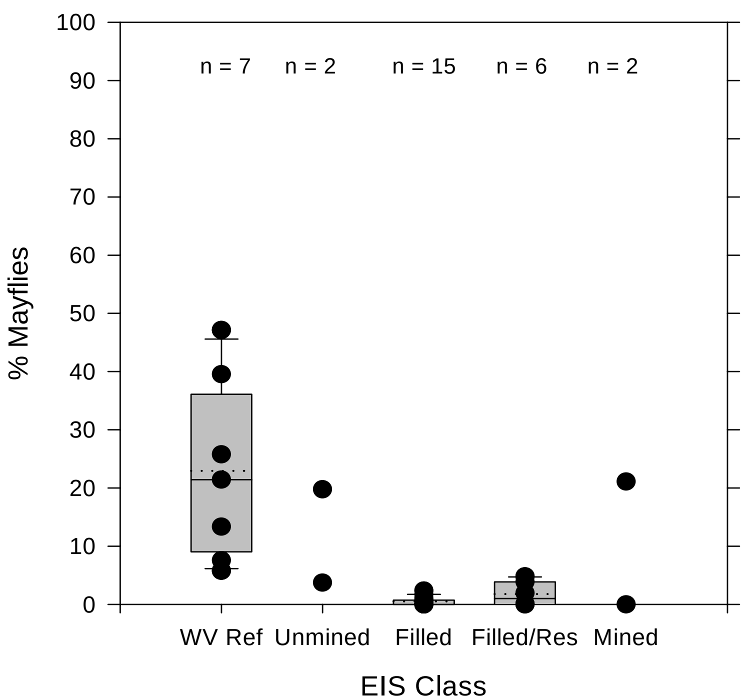


Figure 25. Comparison of % Chironomidae Values
Summer 1999

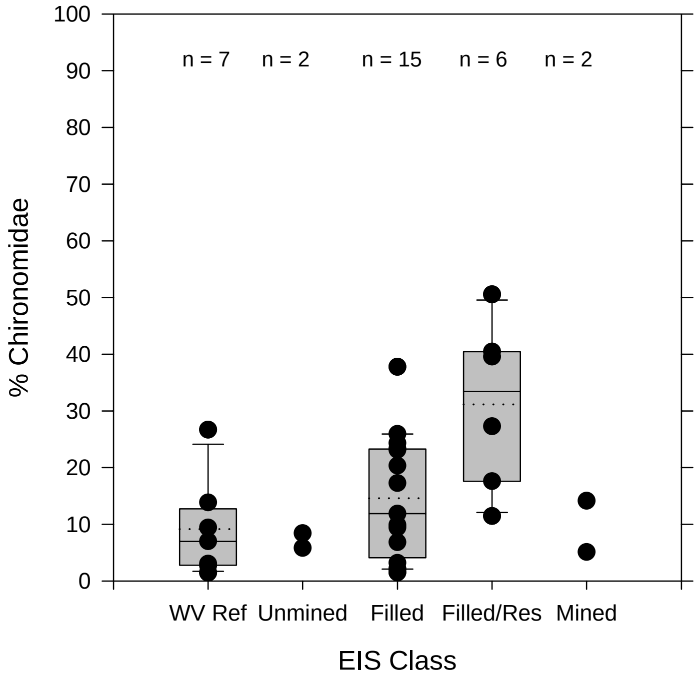


Figure 26. Comparison of WV Stream Condition Index Values
Fall 1999

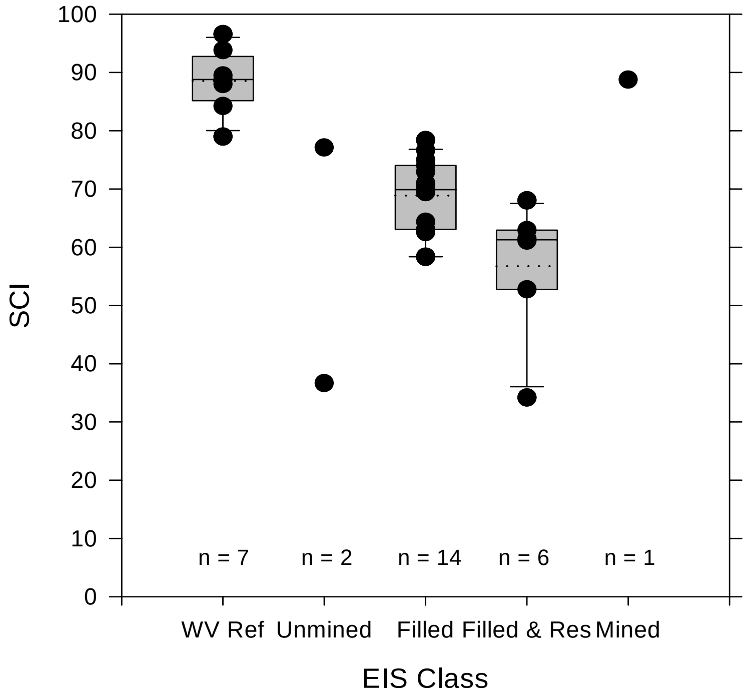


Figure 27. Comparison of Family-Level Total Taxa Values
Fall 1999

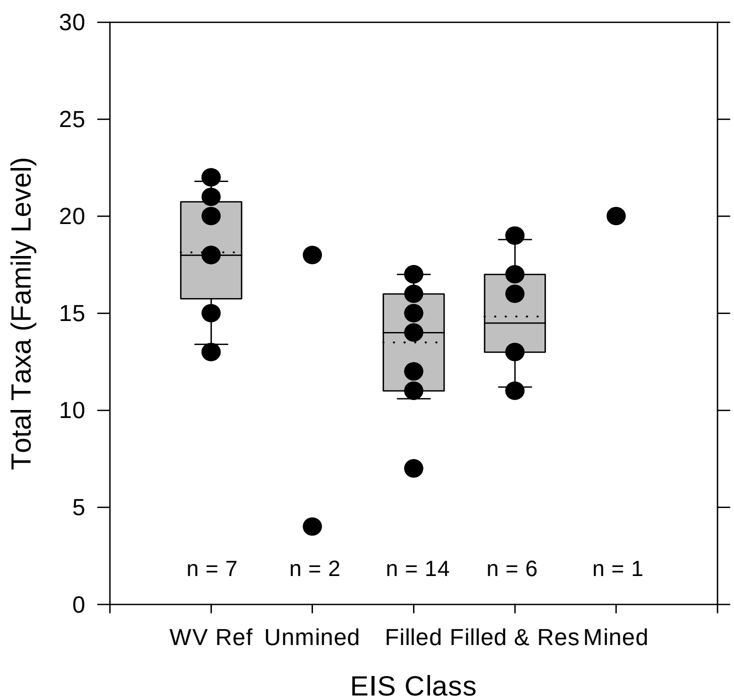


Figure 28. Comparison of Family-Level EPT Taxa Values
Fall 1999

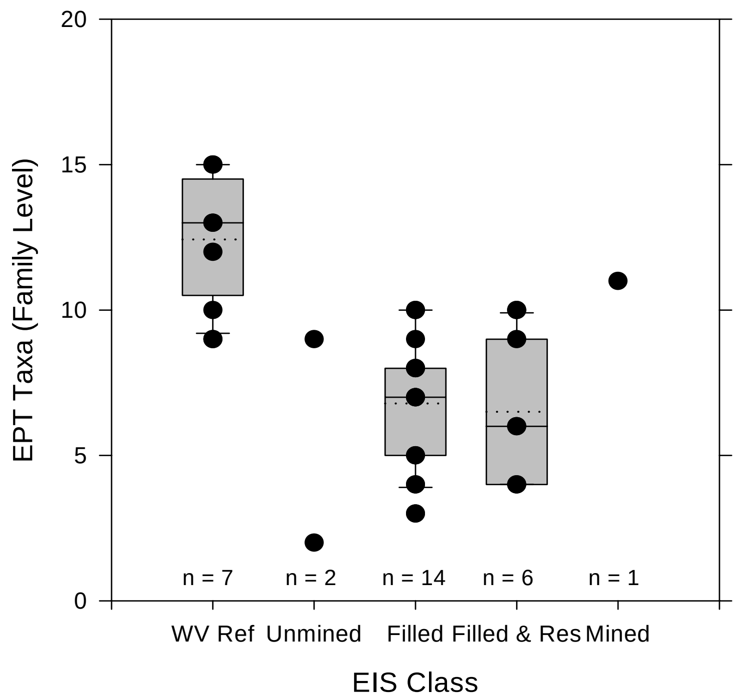


Figure 29. Comparison of % EPT Values
Fall 1999

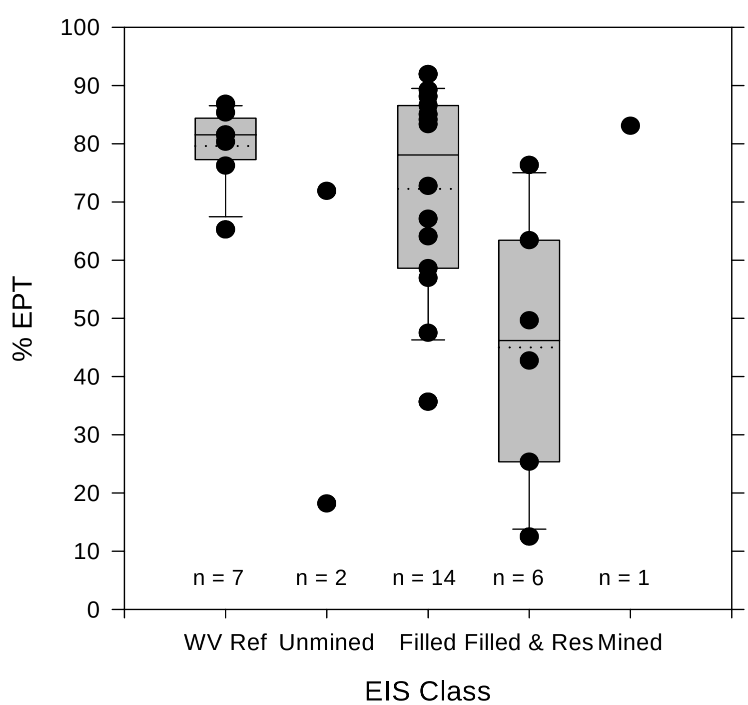


Figure 30. Comparison of HBI Values
Fall 1999

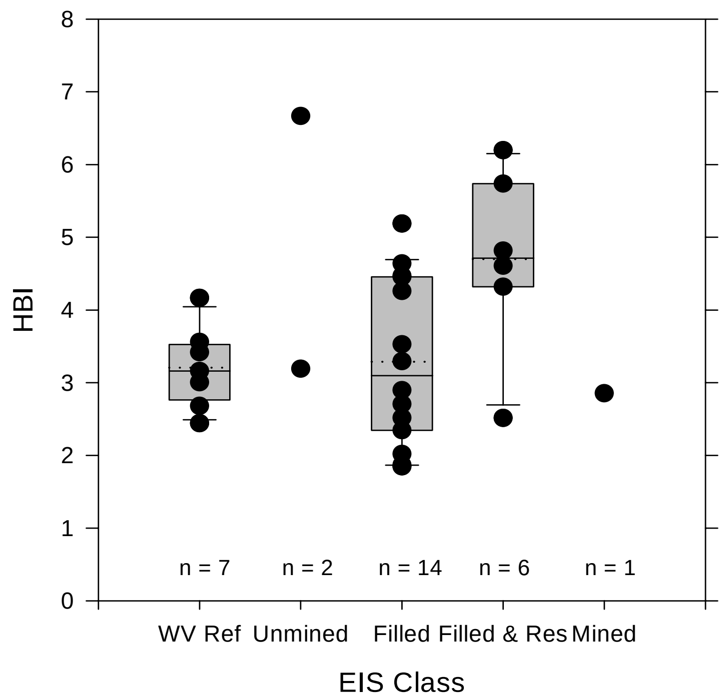


Figure 31. Comparison of %2Dominant Families Values
Fall 1999

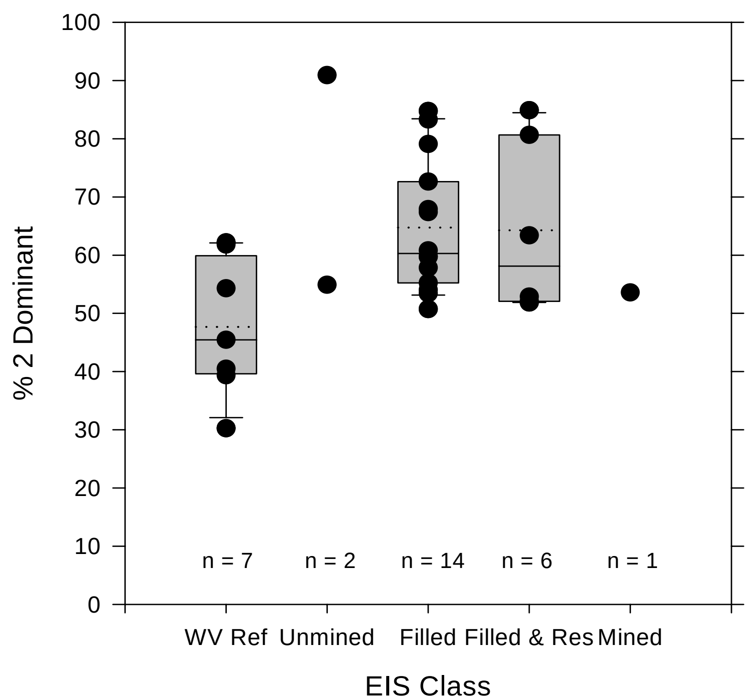


Figure 32. Comparison of Family-Level Mayfly Taxa Values
Fall 1999

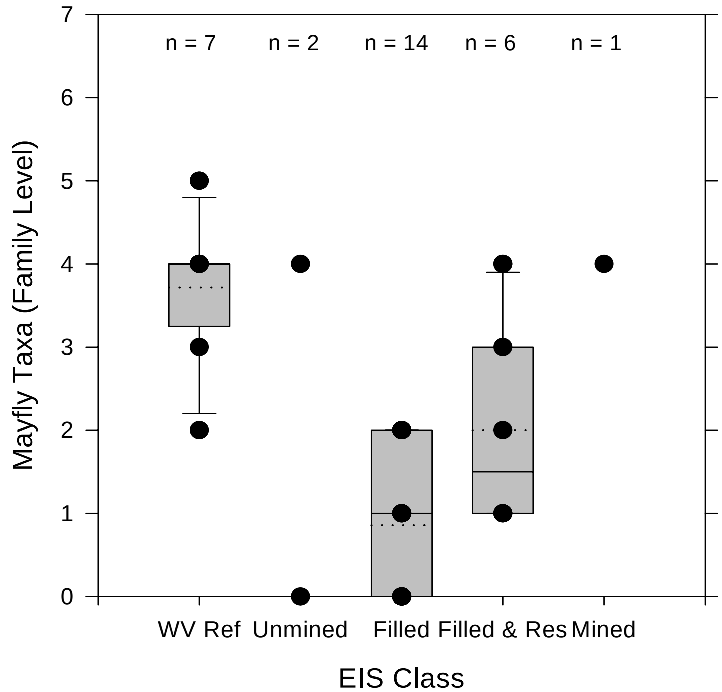


Figure 33. Comparison of % Mayfly Values
Fall 1999

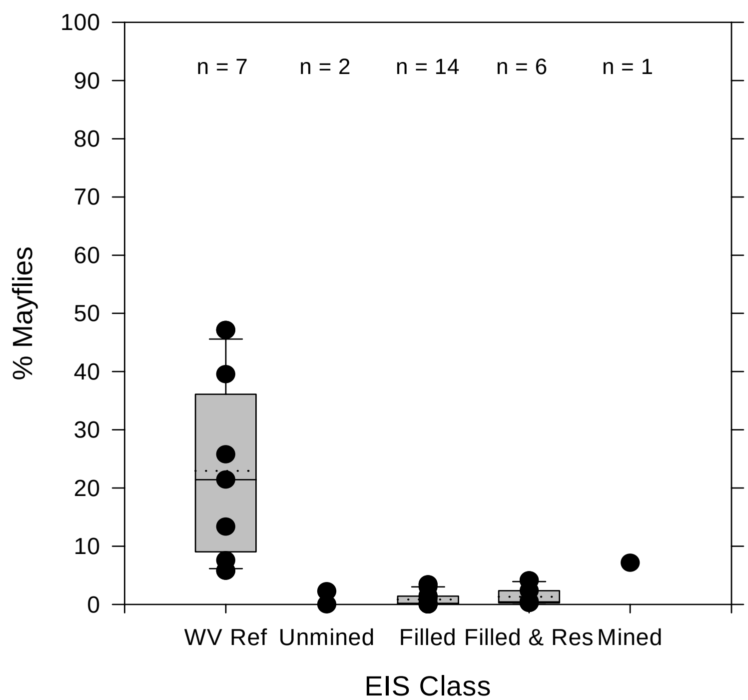


Figure 34. Comparison of % Chironomidae Values
Fall 1999

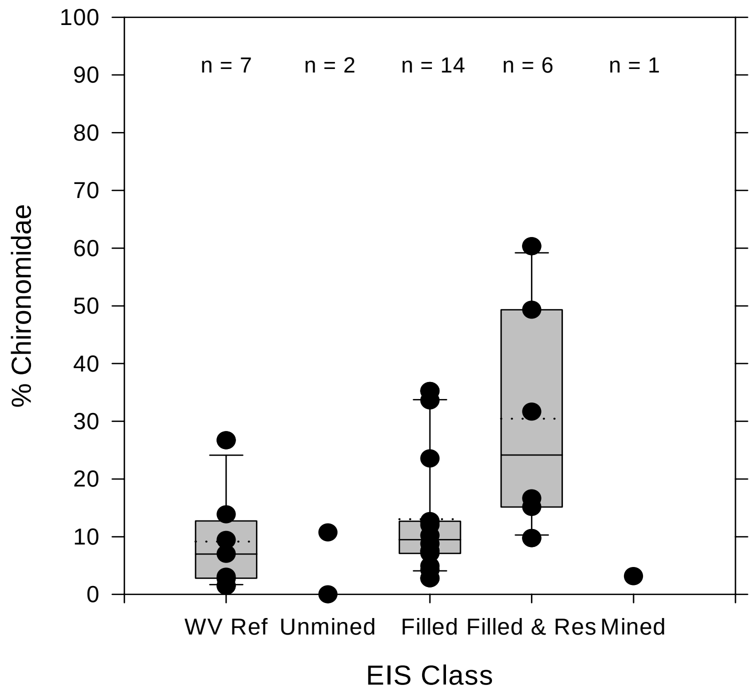


Figure 35. Comparison of WV Stream Condition Index (SCI) Values
Winter 2000

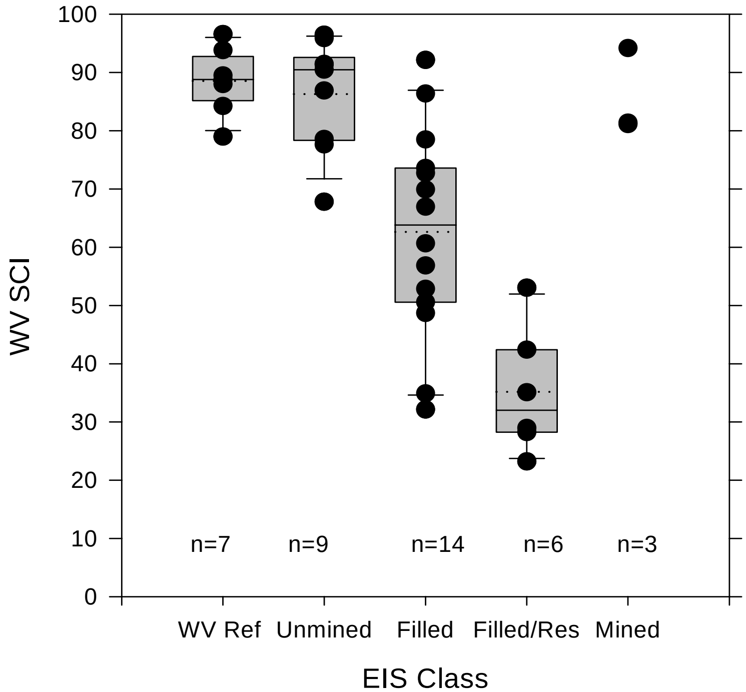


Figure 36. Comparison of Family-Level Total Taxa Values
Winter 2000

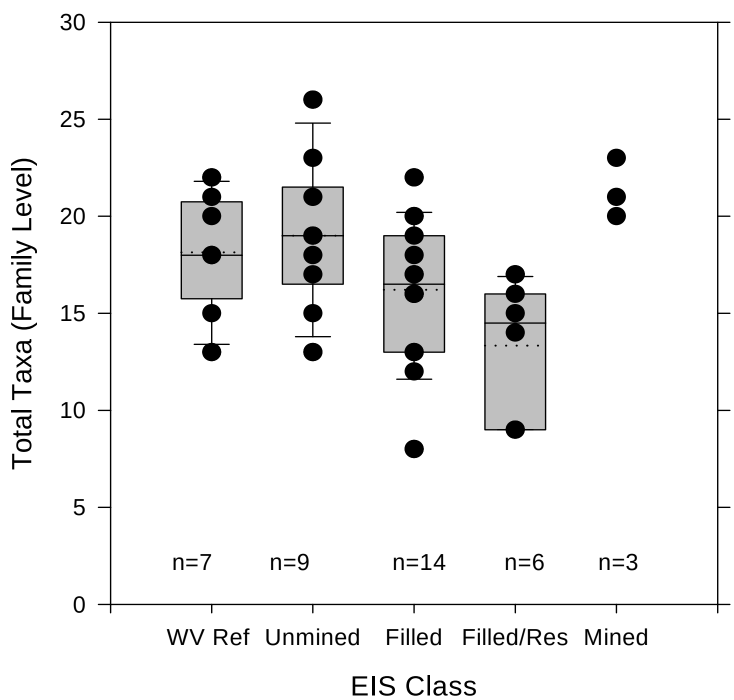


Figure 37. Comparison of Family-Level EPT Taxa Values
Winter 2000

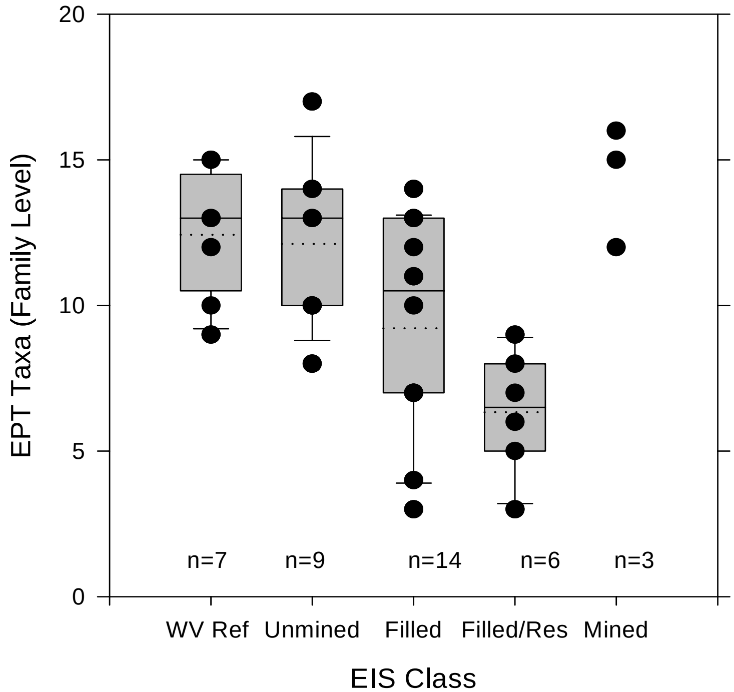


Figure 38. Comparison of % EPT Values
Winter 2000

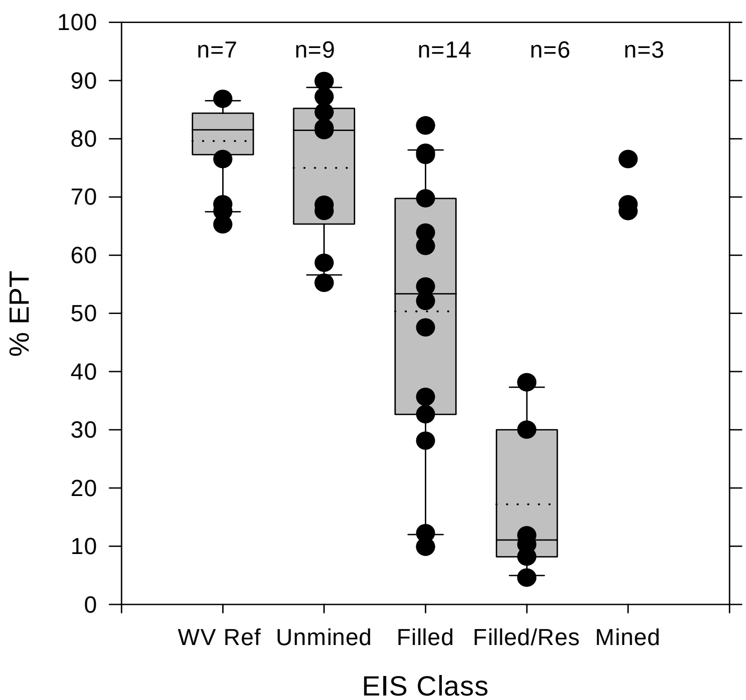


Figure 39. Comparison of HBI Values
Winter 2000

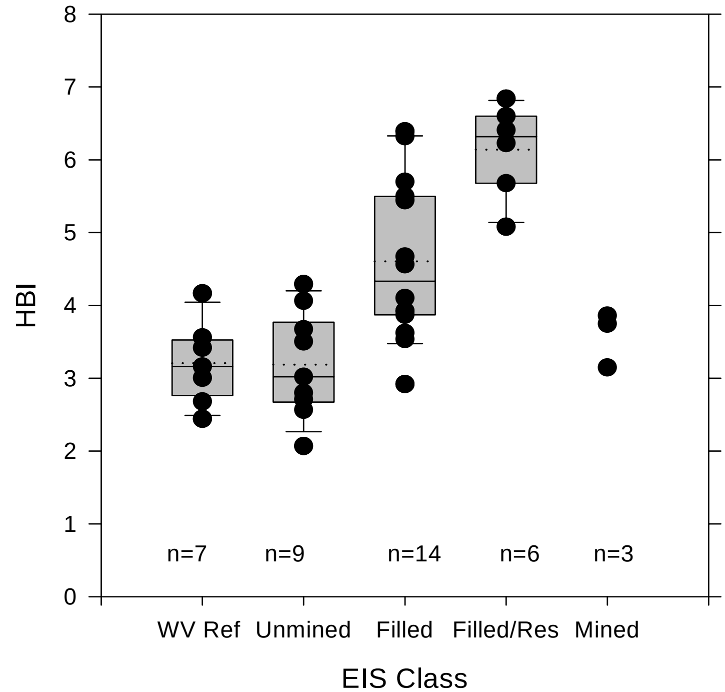


Figure 40. Comparison of % Two Dominant Families Values
Winter 2000

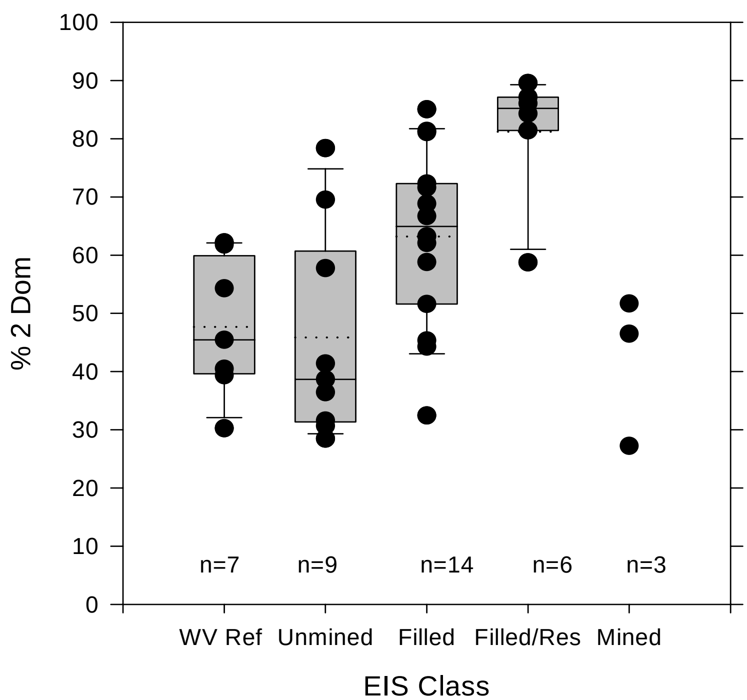


Figure 41. Comparison of Family-Level Mayfly Taxa Values
Winter 2000

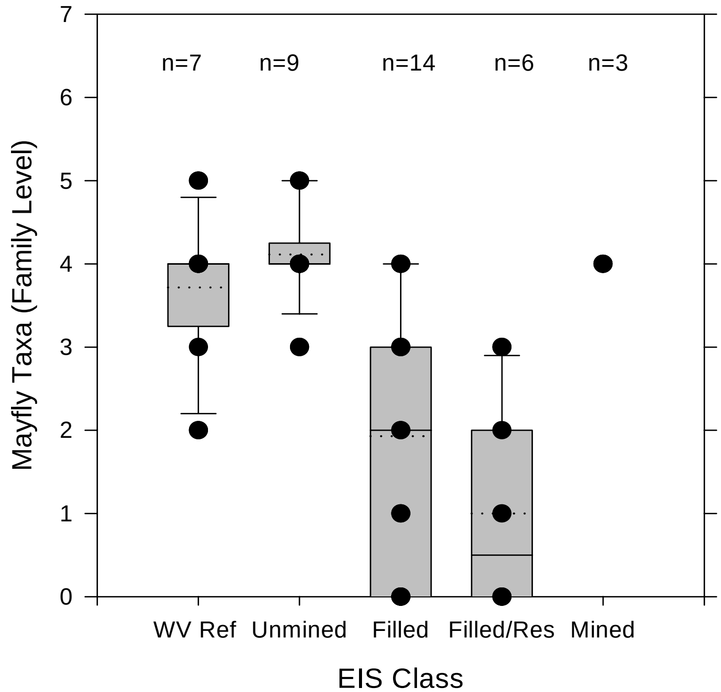


Figure 42. Comparison of % Mayfly Values
Winter 2000

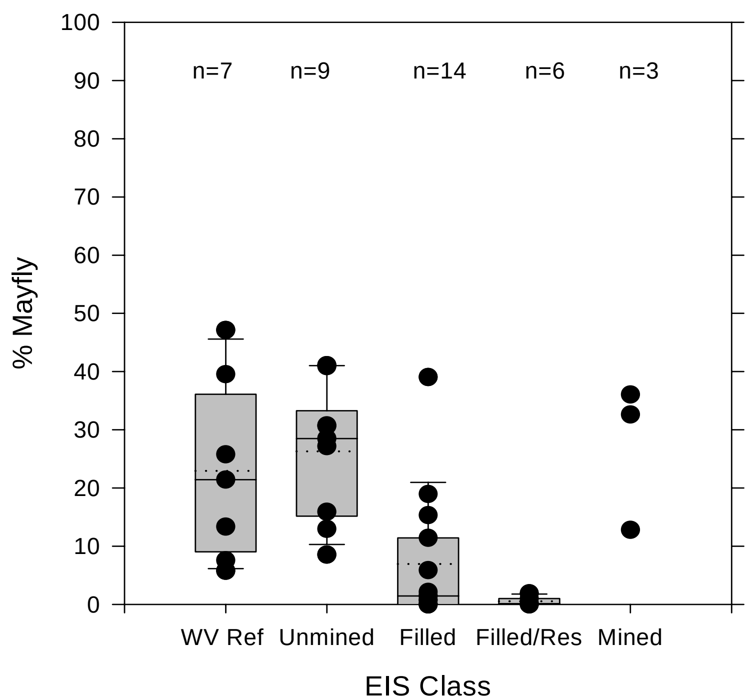


Figure 43. Comparison of % Chironomidae Values Winter 2000

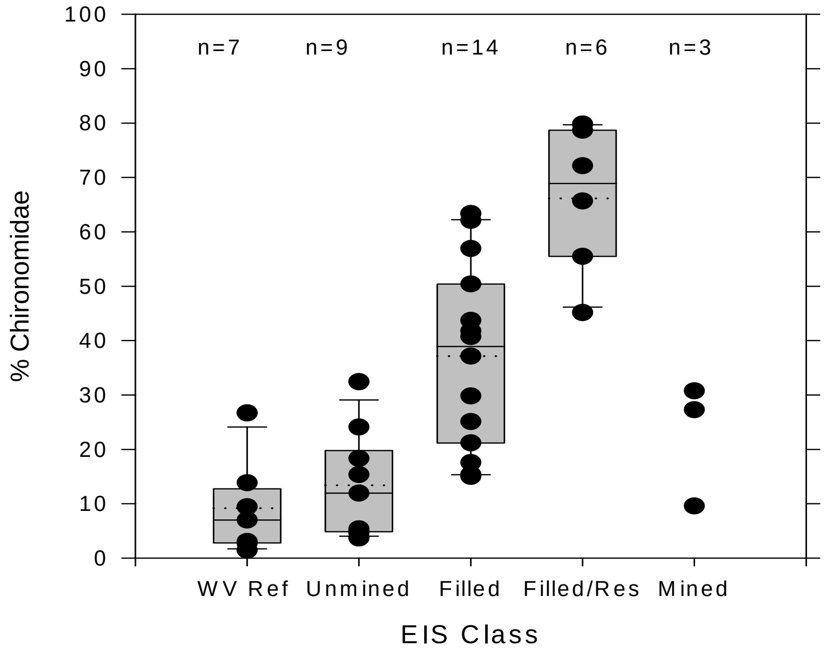


Figure 44. Comparison of WV Stream Condition Index (SCI) Values
Spring 2000

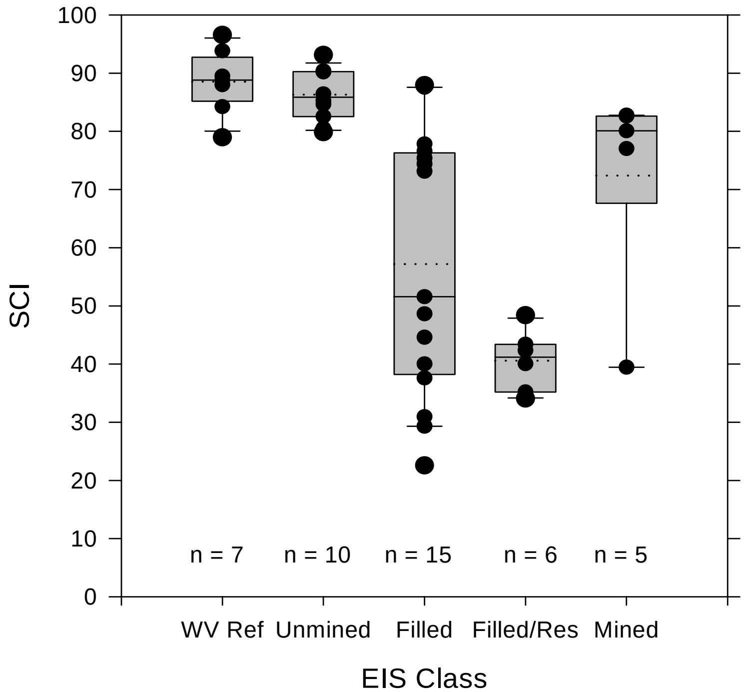


Figure 45. Comparison of Family-Level Total Taxa Values
Spring 2000

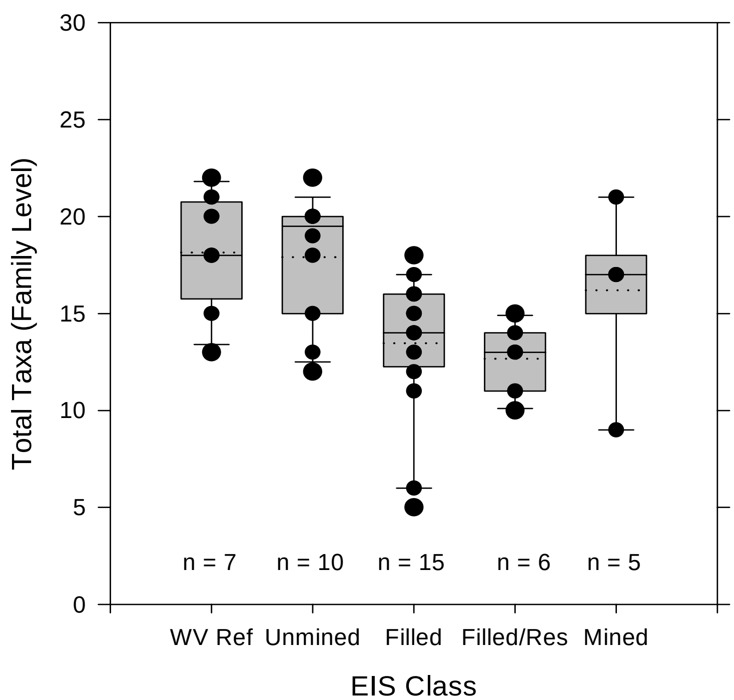


Figure 46. Comparison of Family-Level EPT Values Spring 2000

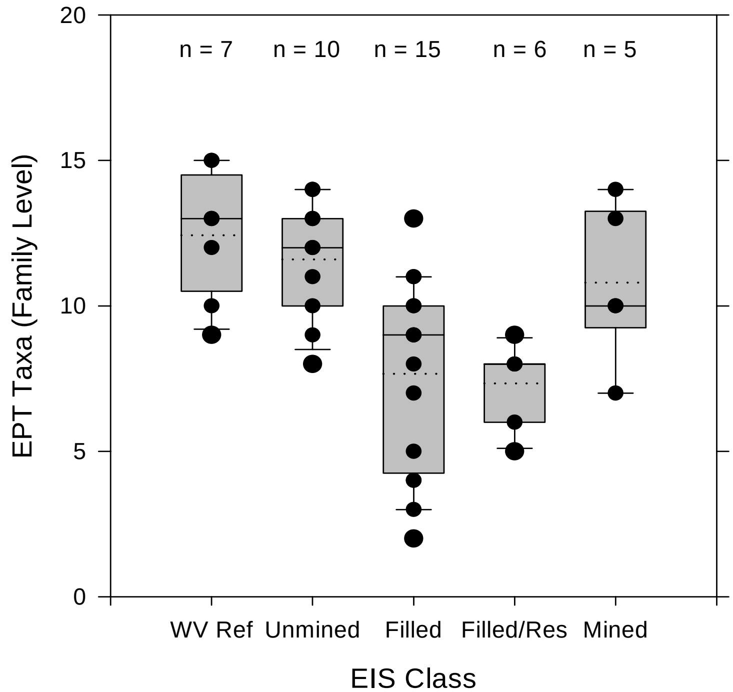


Figure 47. Comparison of %EPT Values Spring 2000

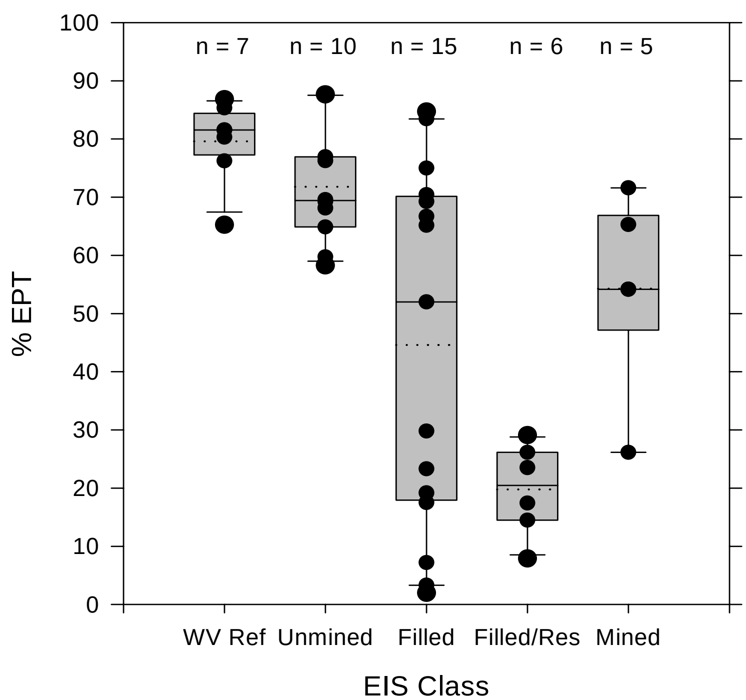


Figure 48. Comparison of HBI Values
Spring 2000

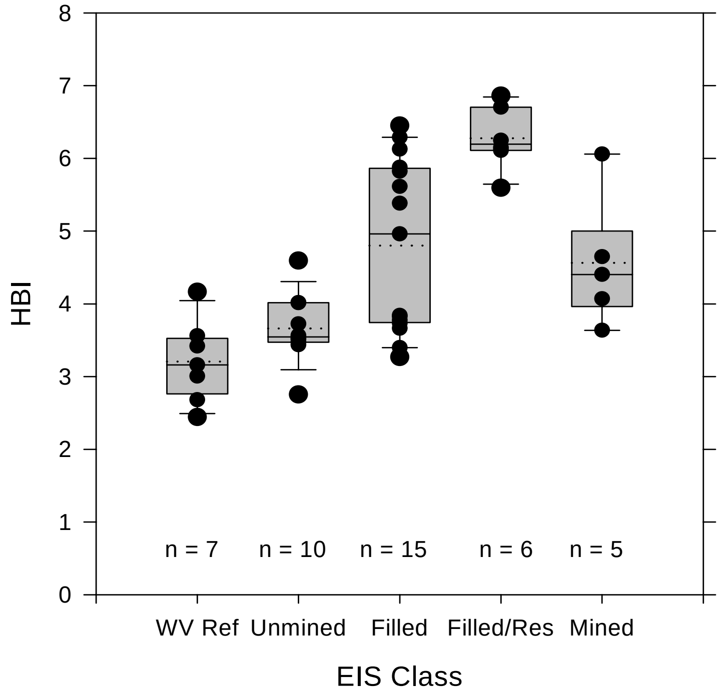


Figure 49. Comparison of % Two Dominant Families Values
Spring 2000

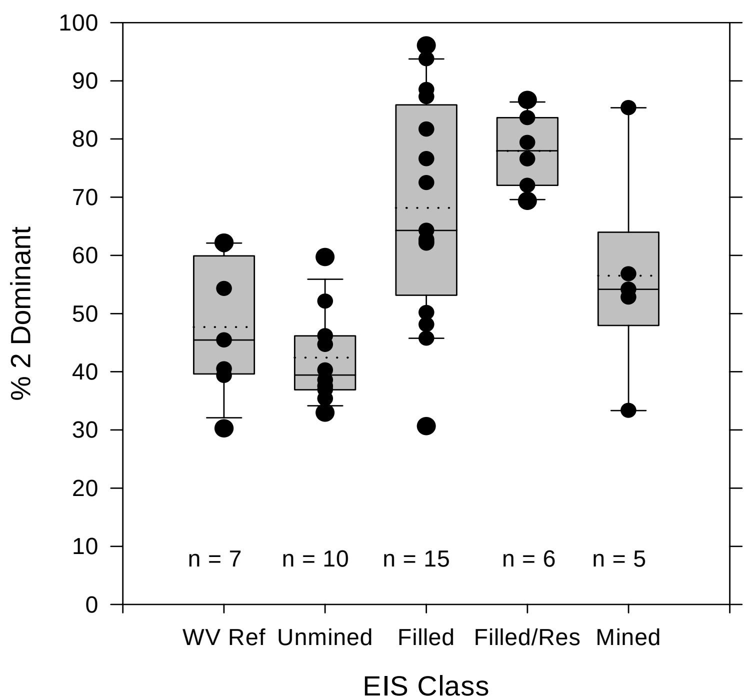


Figure 50. Comparison of Family-Level Mayfly Taxa Values
Spring 2000

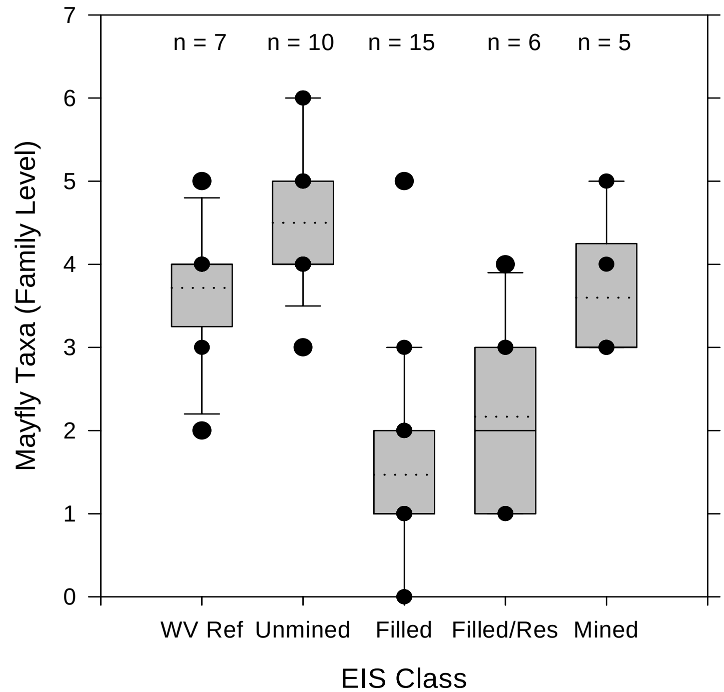


Figure 51. Comparison of %Mayfly Values
Spring 2000

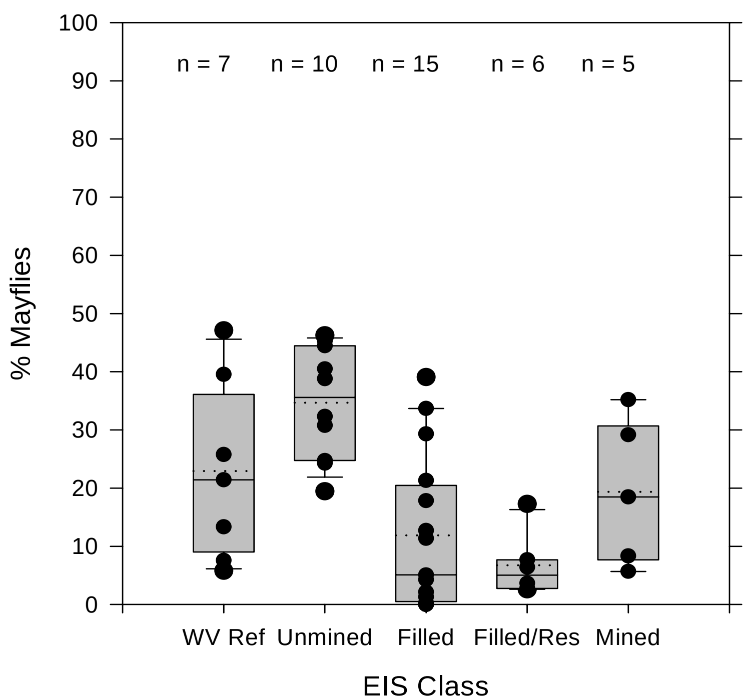


Figure 52. Comparison of % Chironomidae Values
Spring 2000

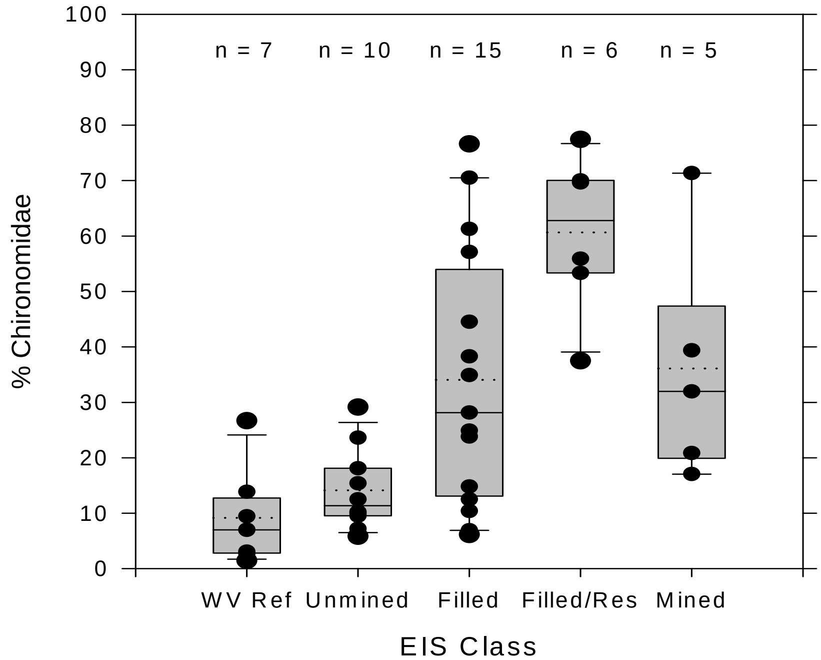


Figure 53. Comparison of Conductivity
Spring 1999

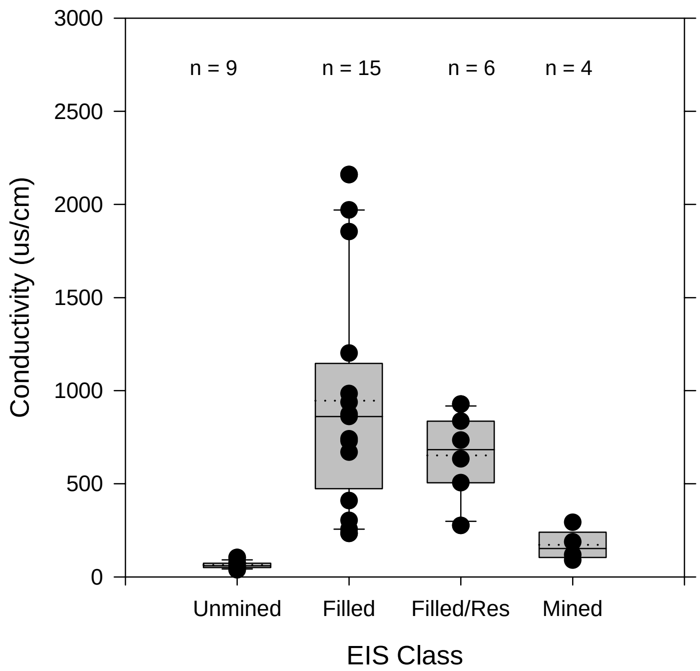


Figure 54. Comparison of pH
Spring 1999

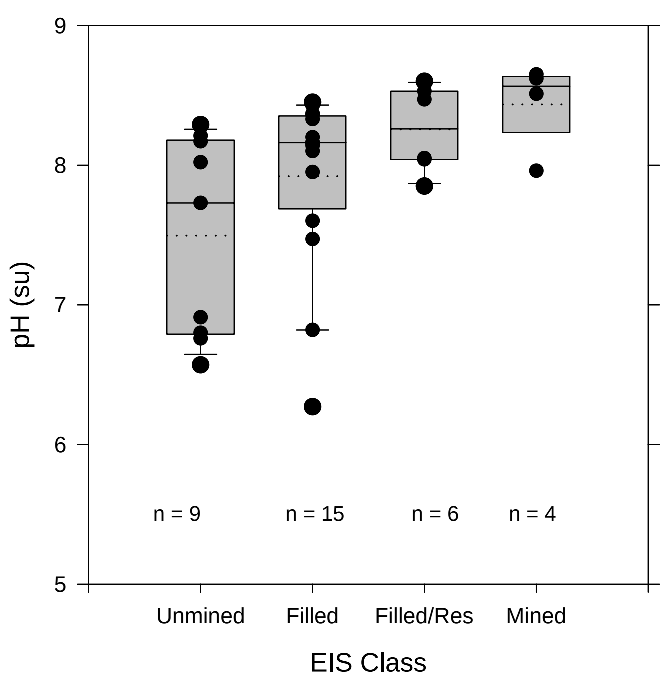


Figure 55. Comparison of Temperature
Spring 1999

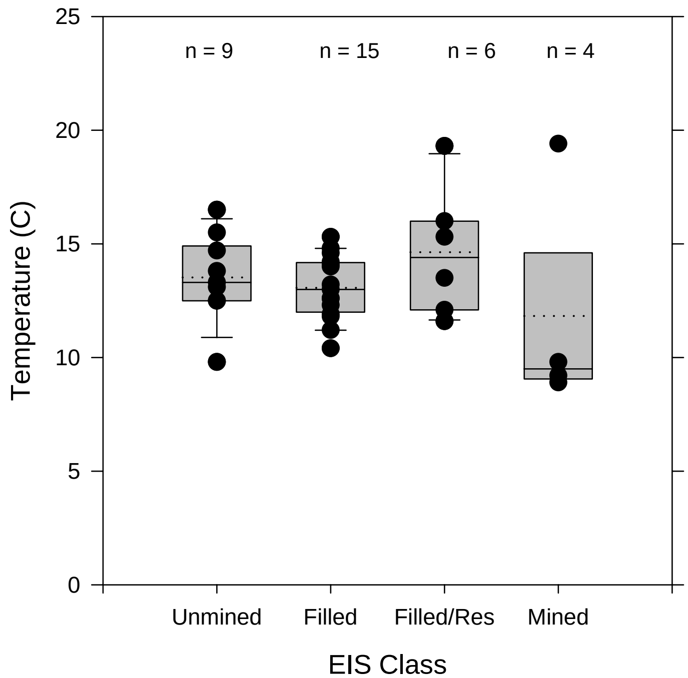


Figure 56. Comparison of Conductivity
Summer 1999

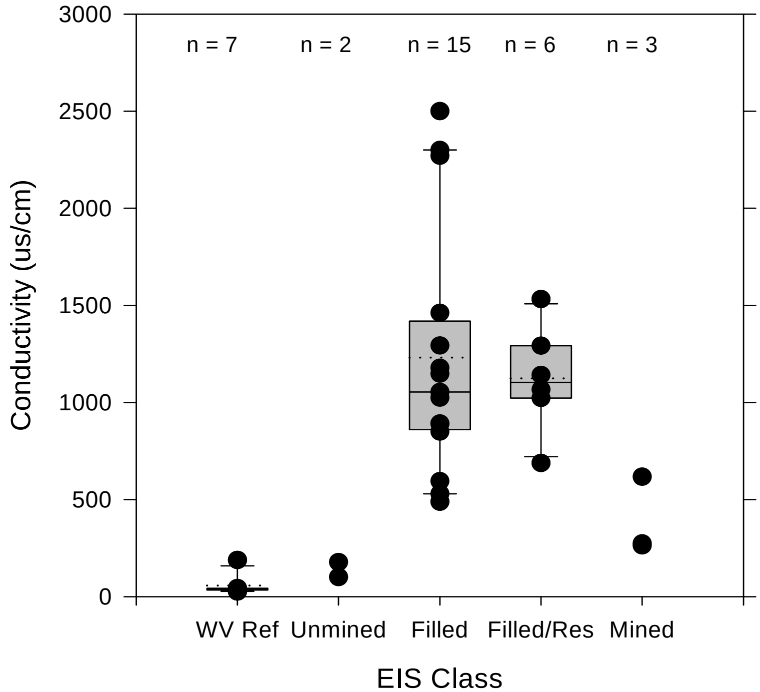


Figure 57. Comparison of pH
Summer 1999

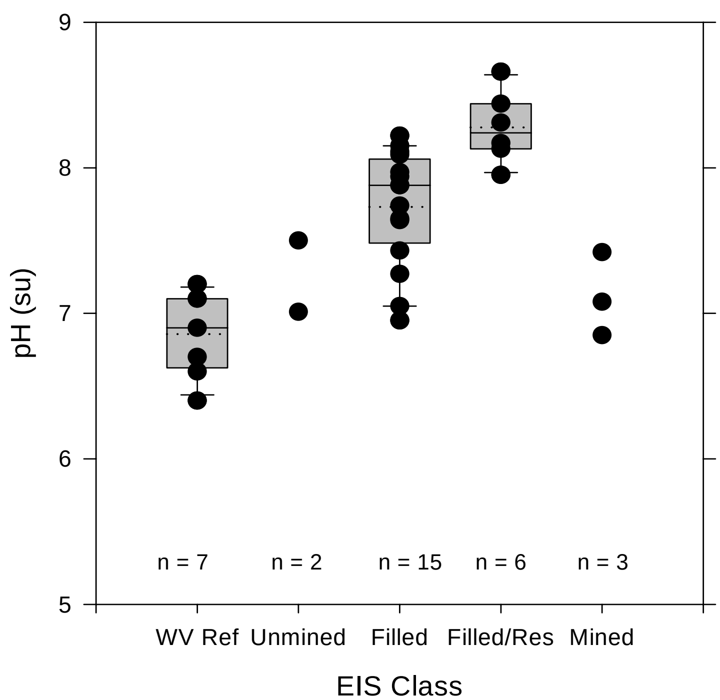
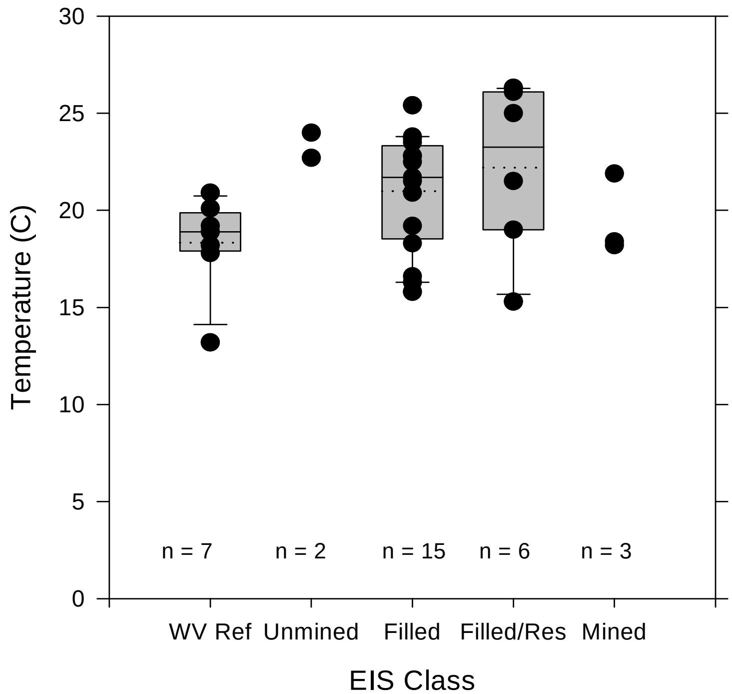


Figure 58. Comparison of Temperature
Summer 1999



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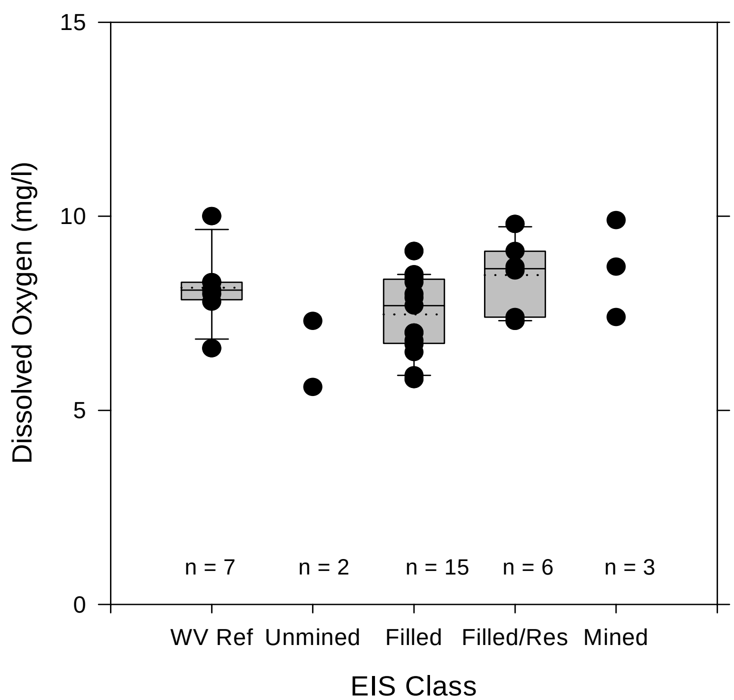

Figure 60. Comparison of Conductivity
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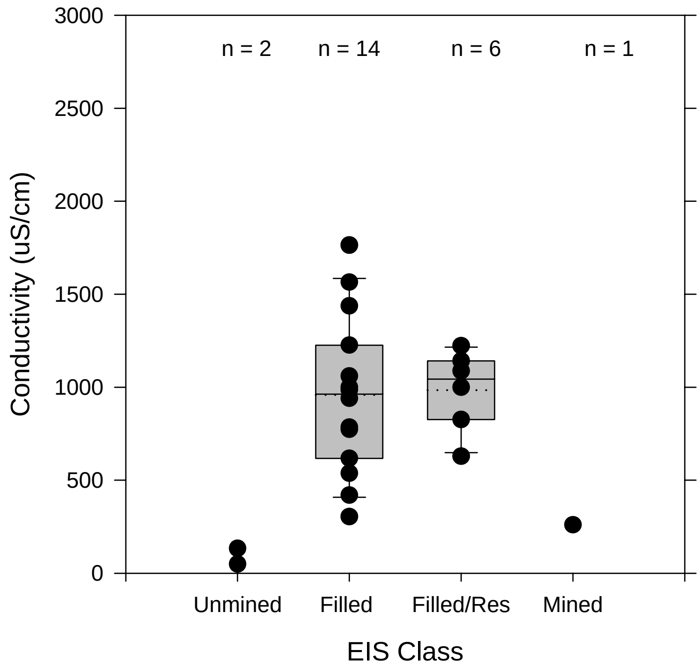

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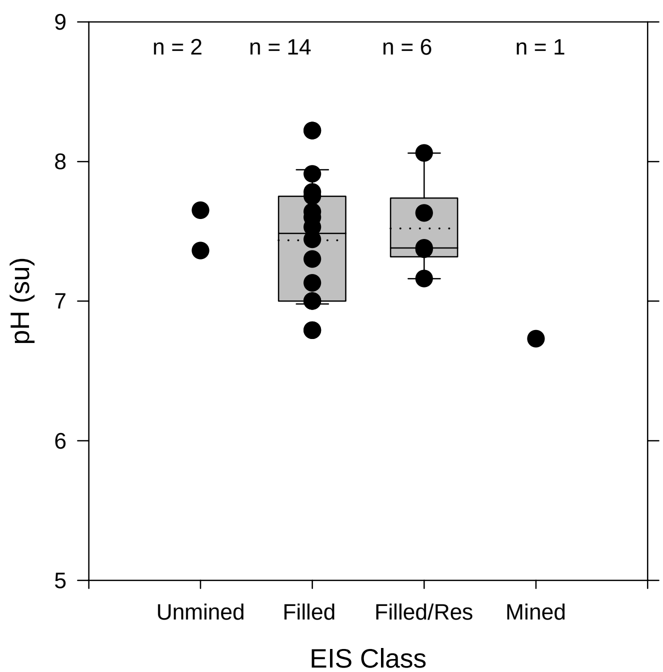

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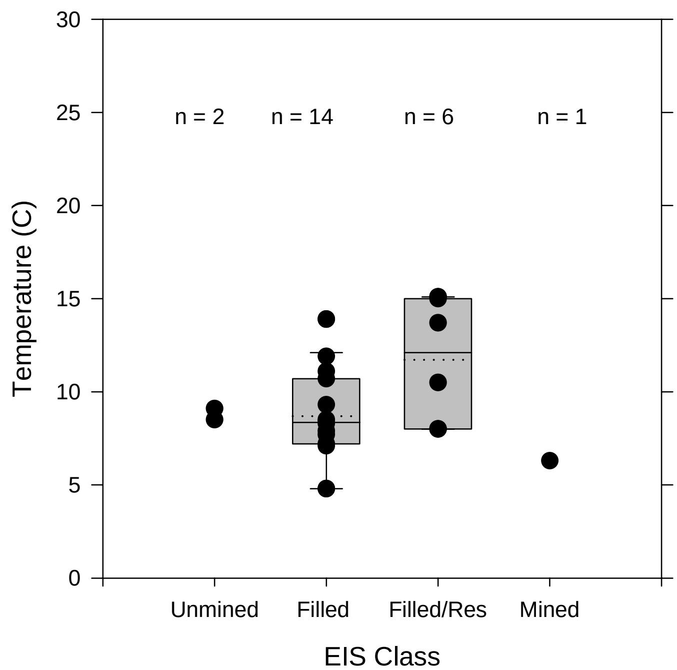

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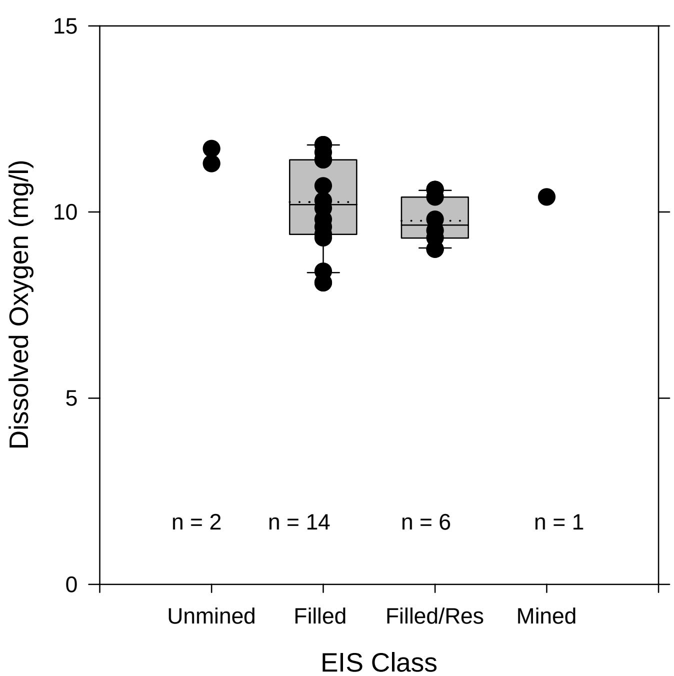

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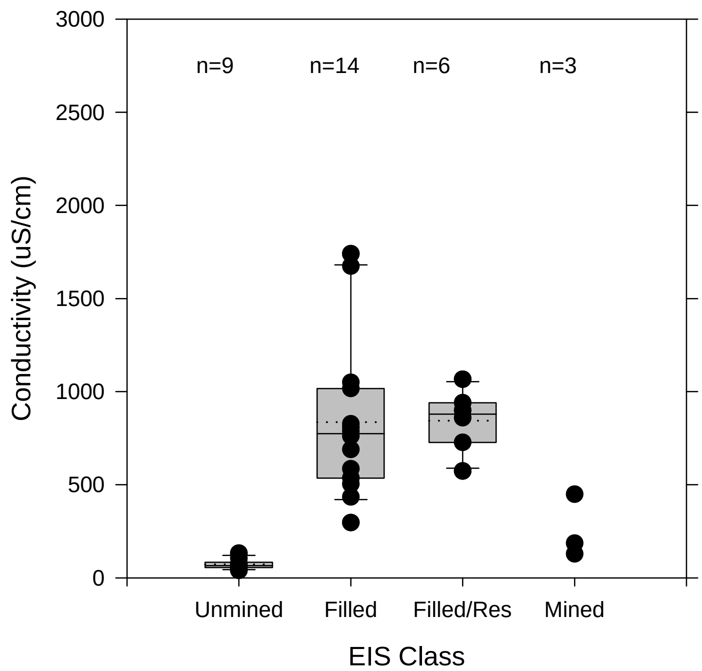

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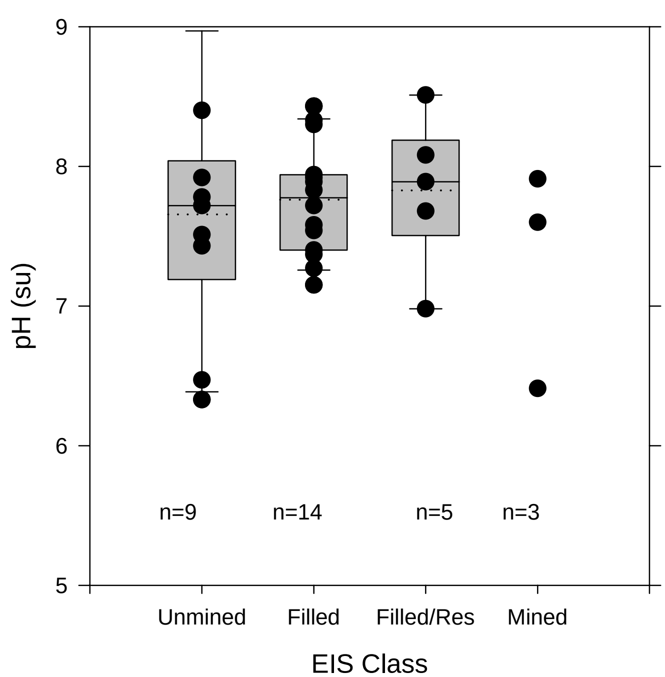

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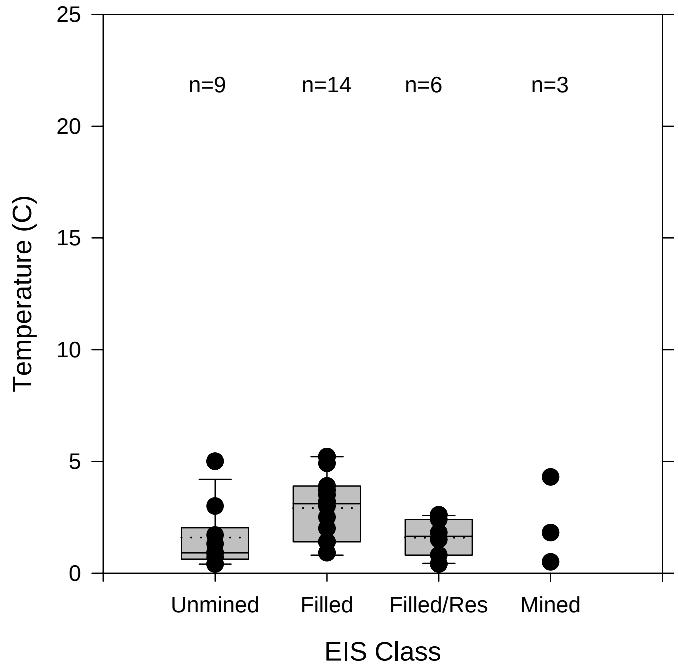

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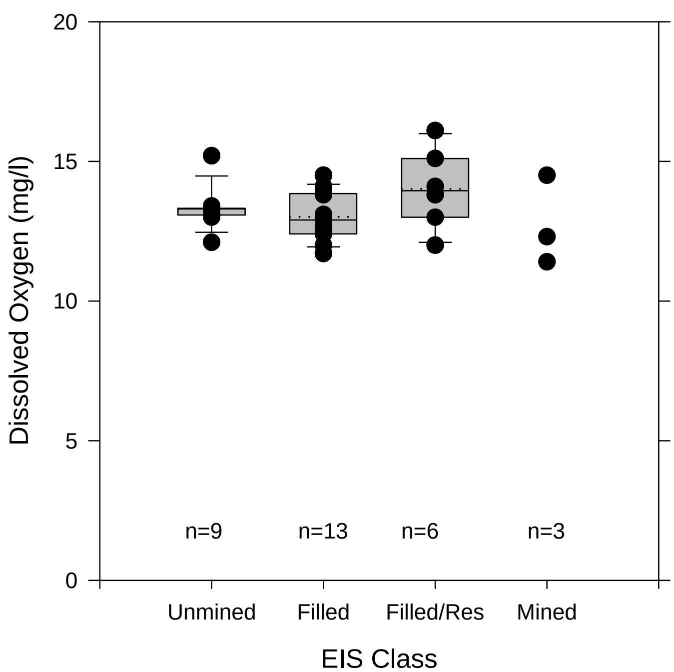

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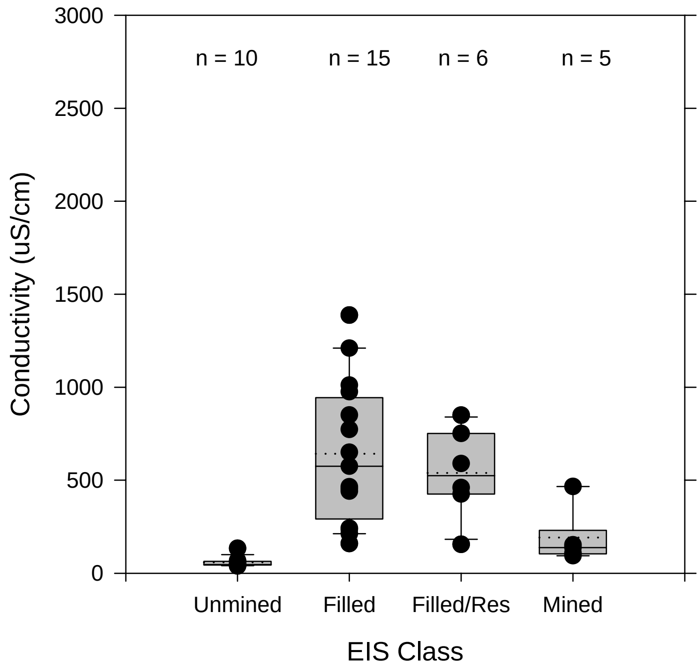

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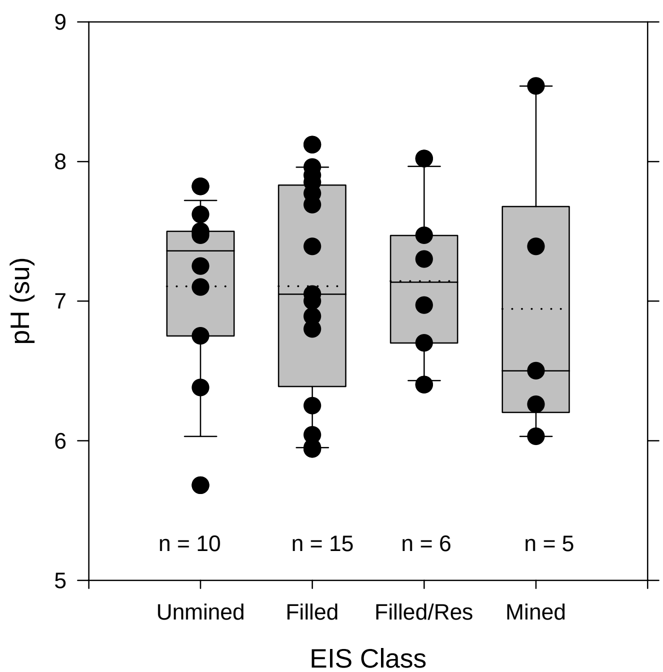

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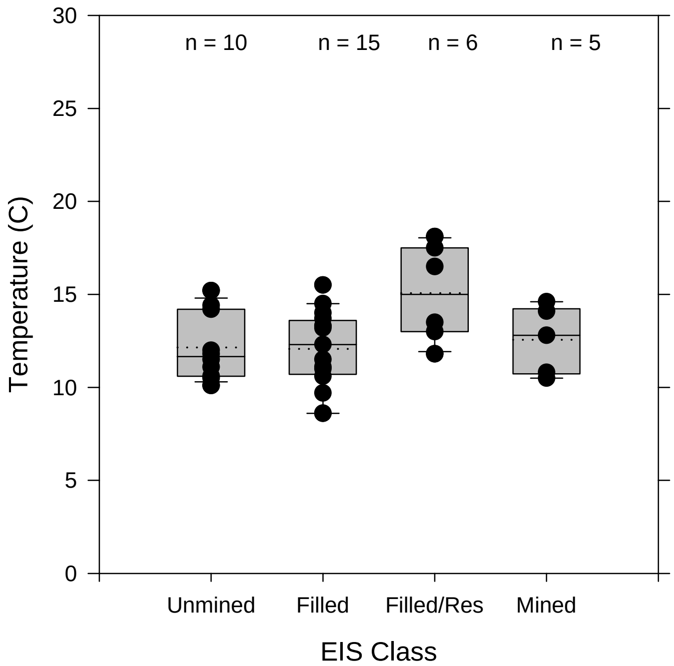

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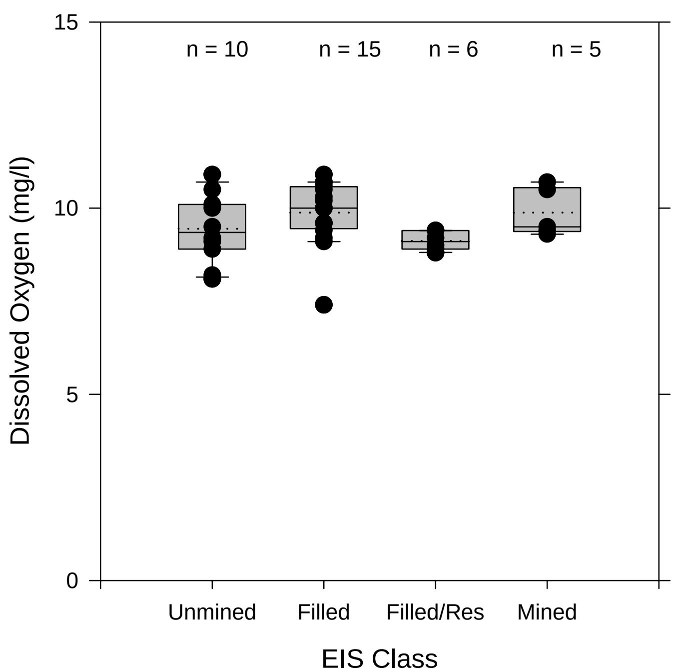

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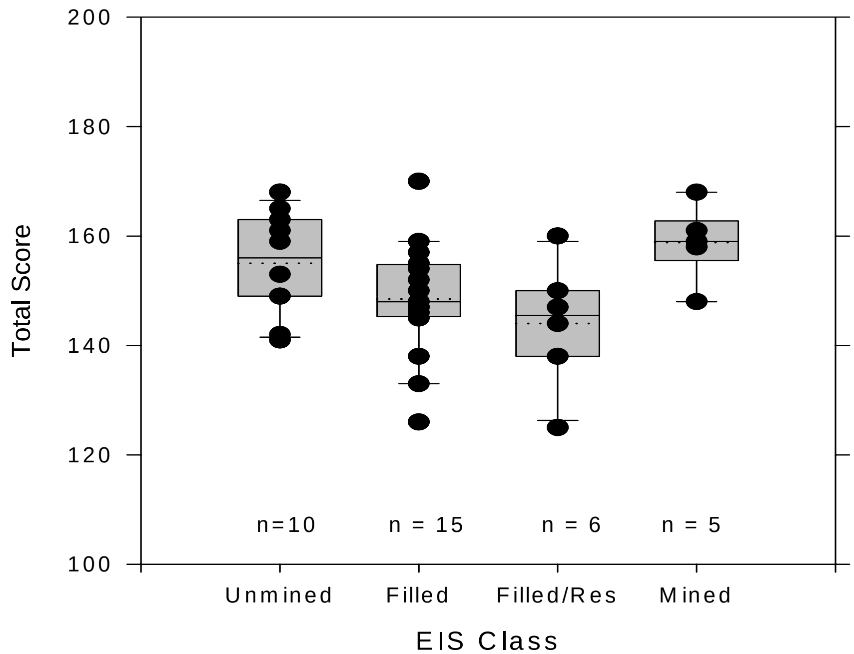
Spring 2000



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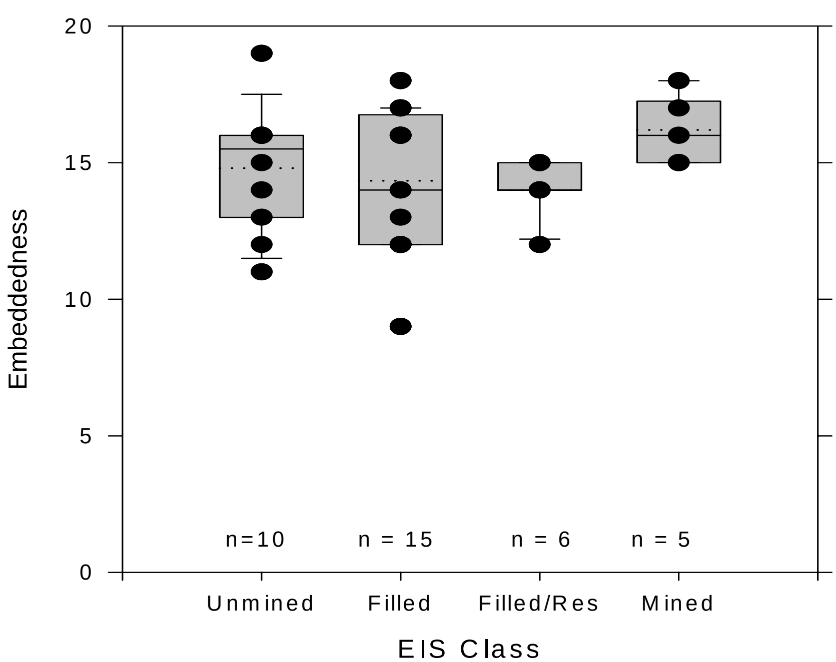

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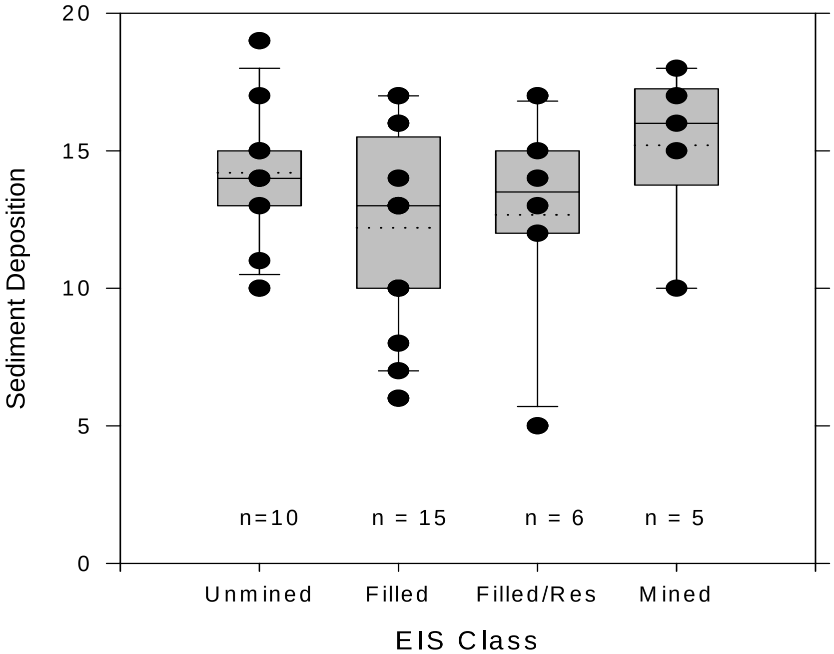

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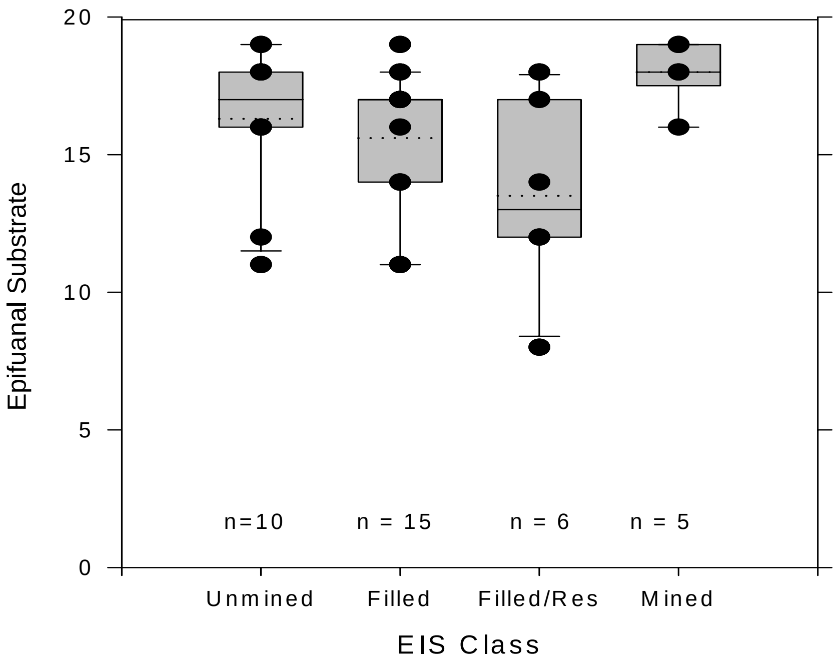

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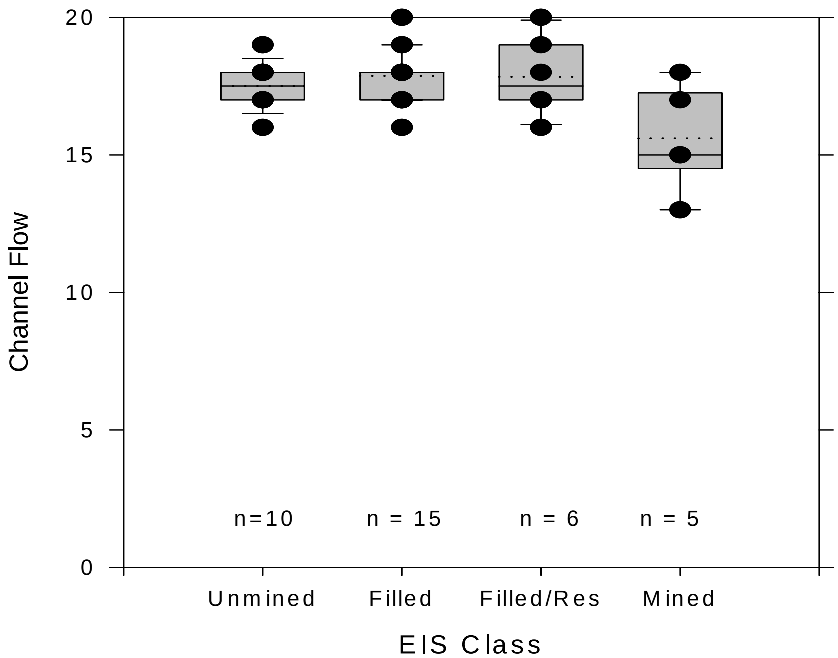

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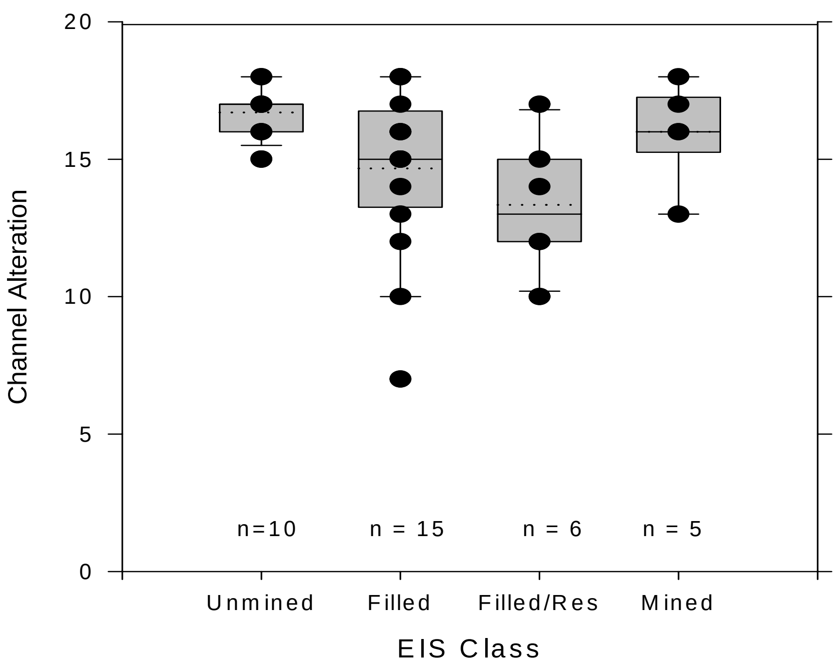

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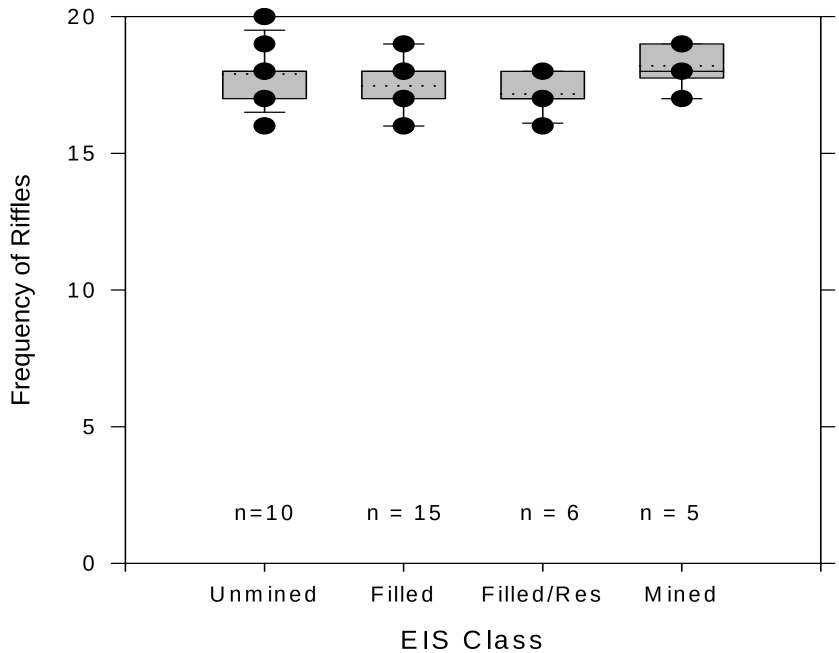

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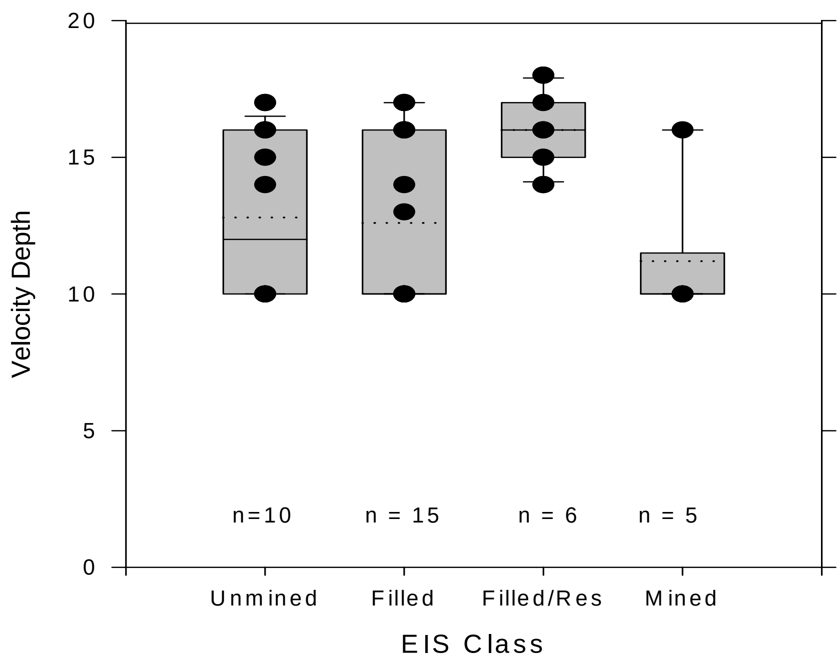

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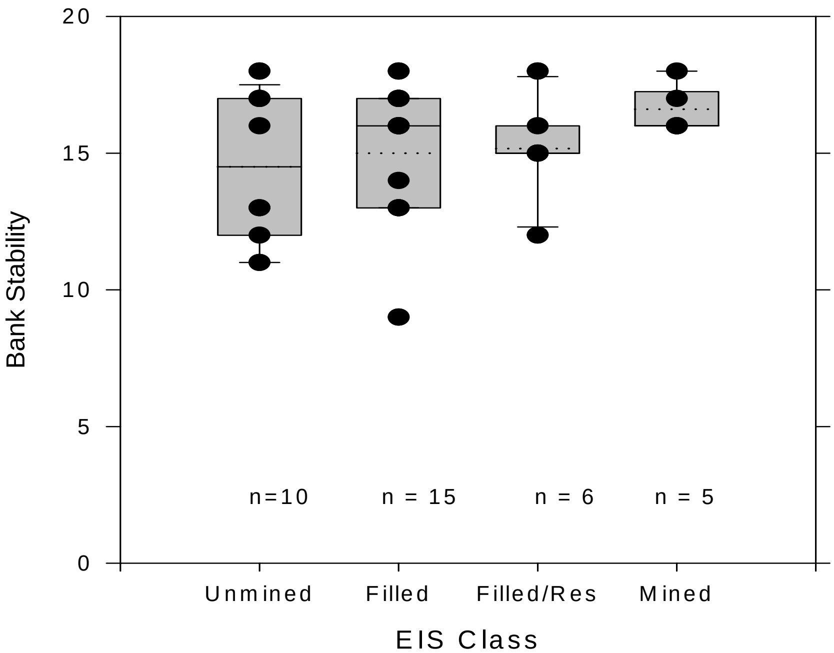

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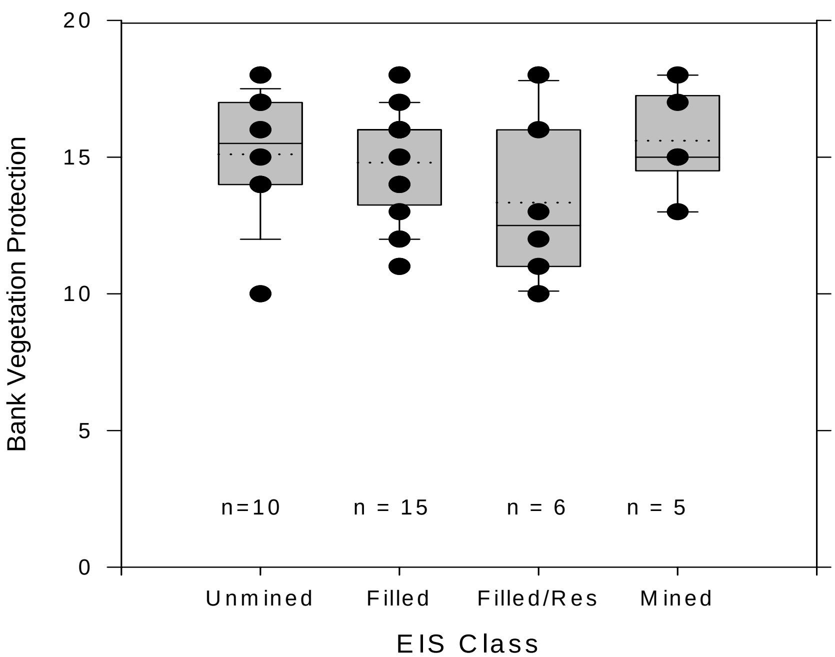

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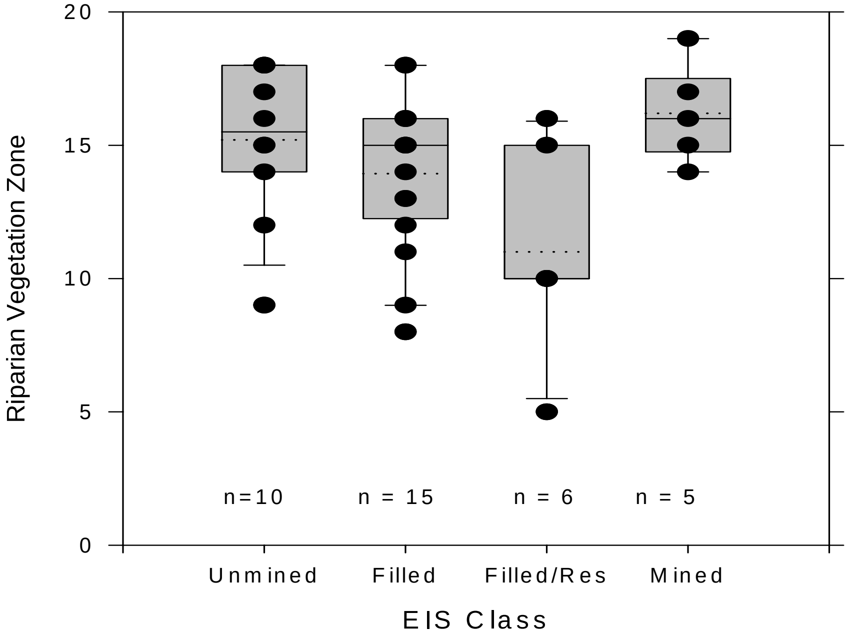

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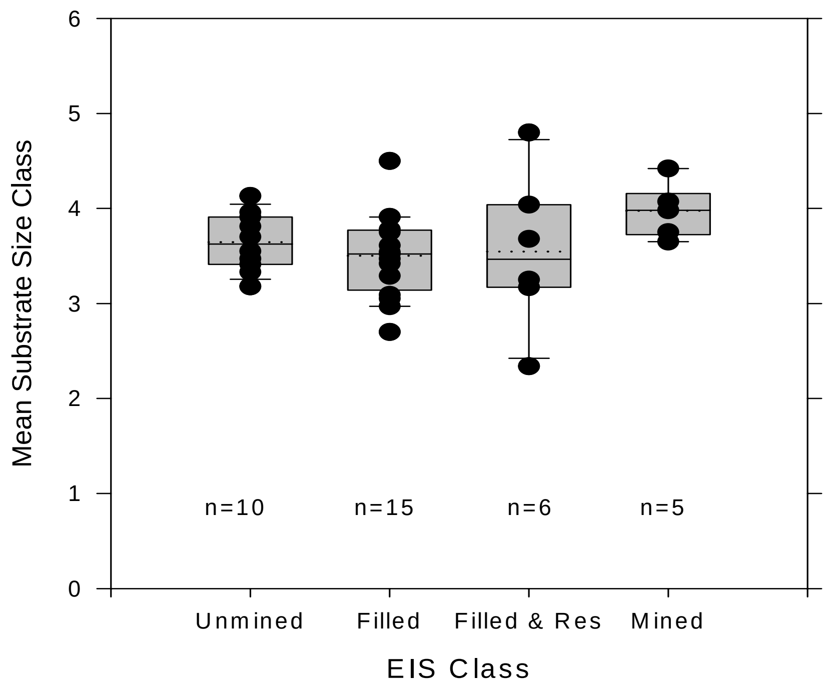

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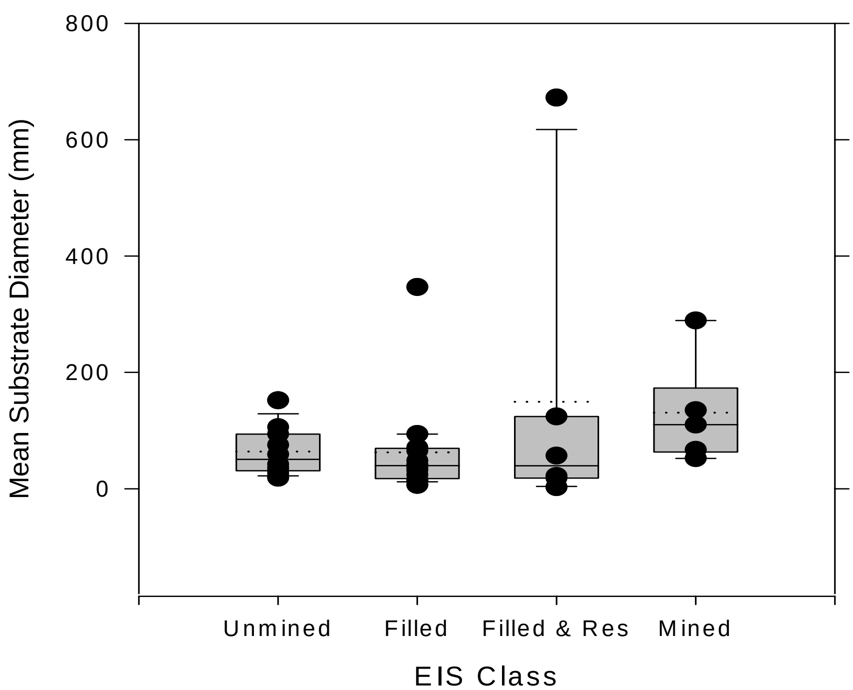

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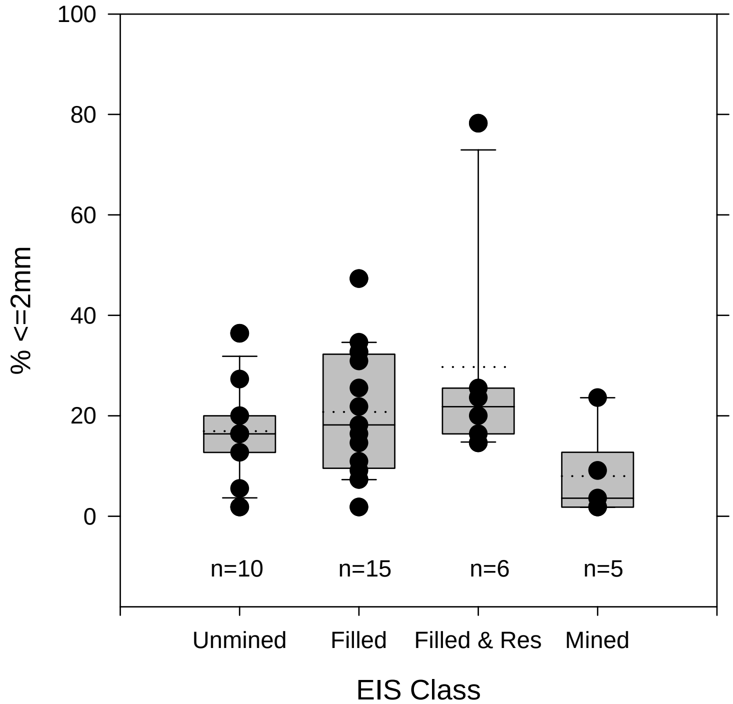

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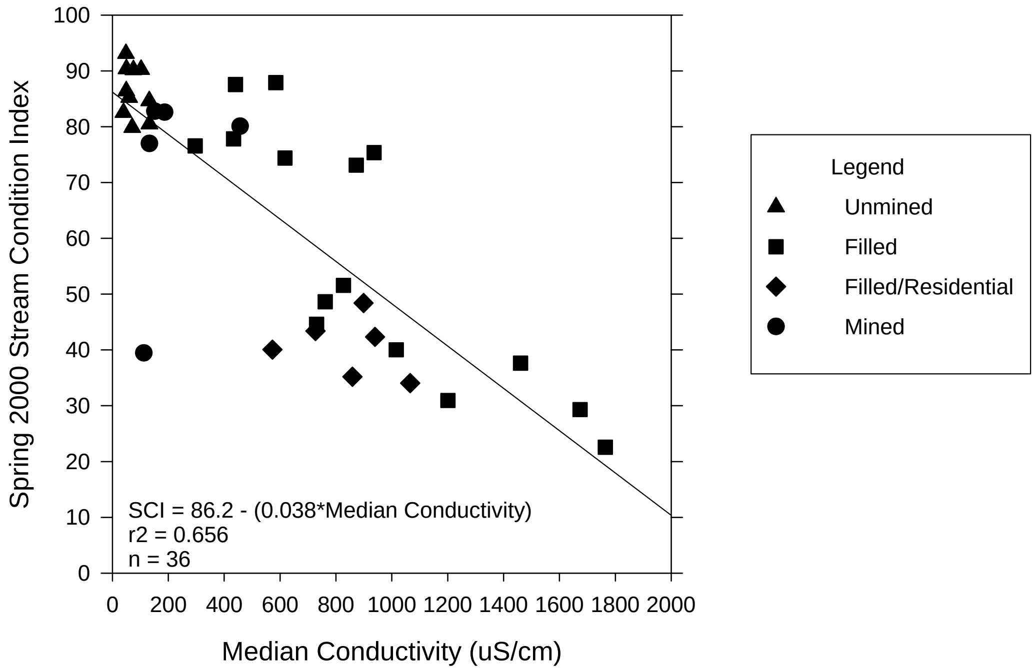

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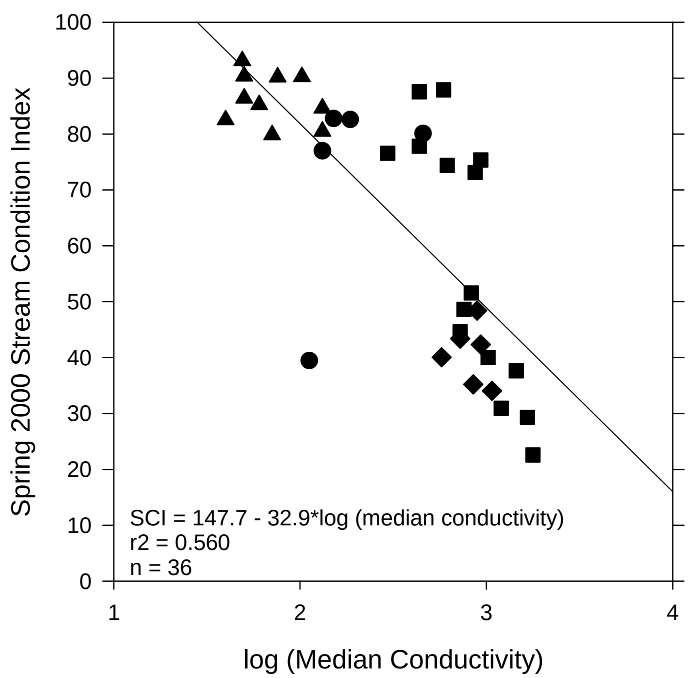

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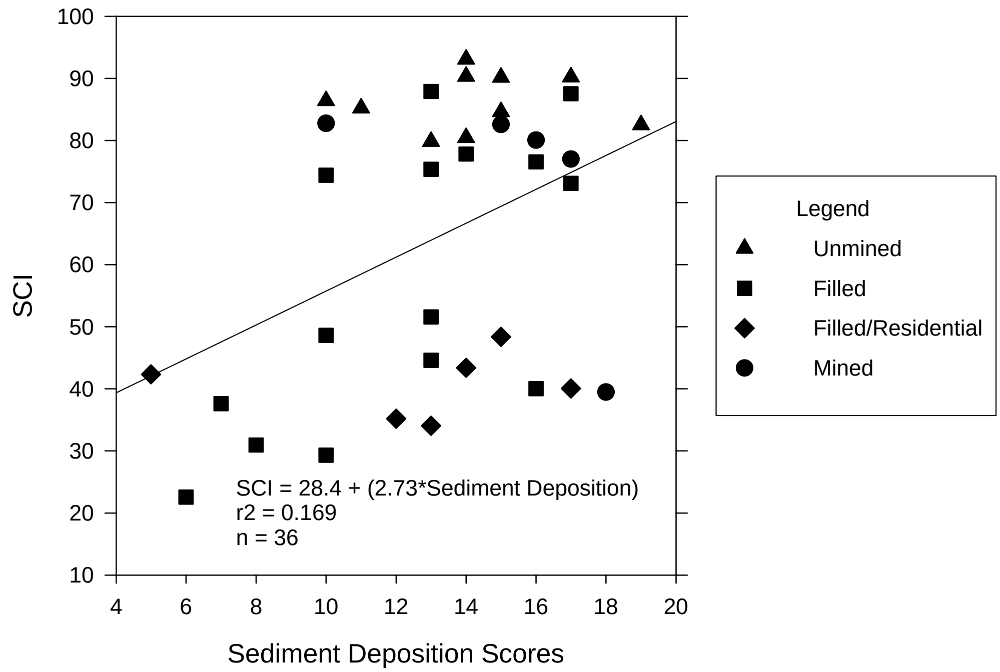

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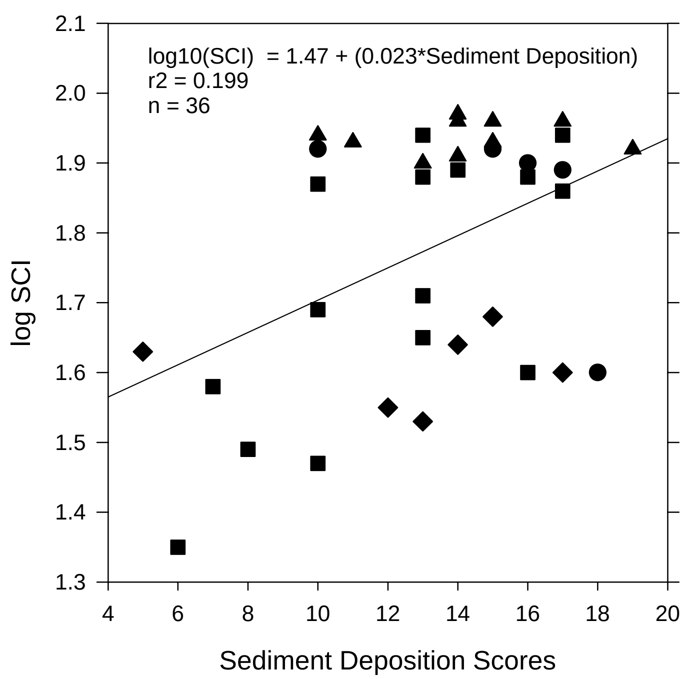

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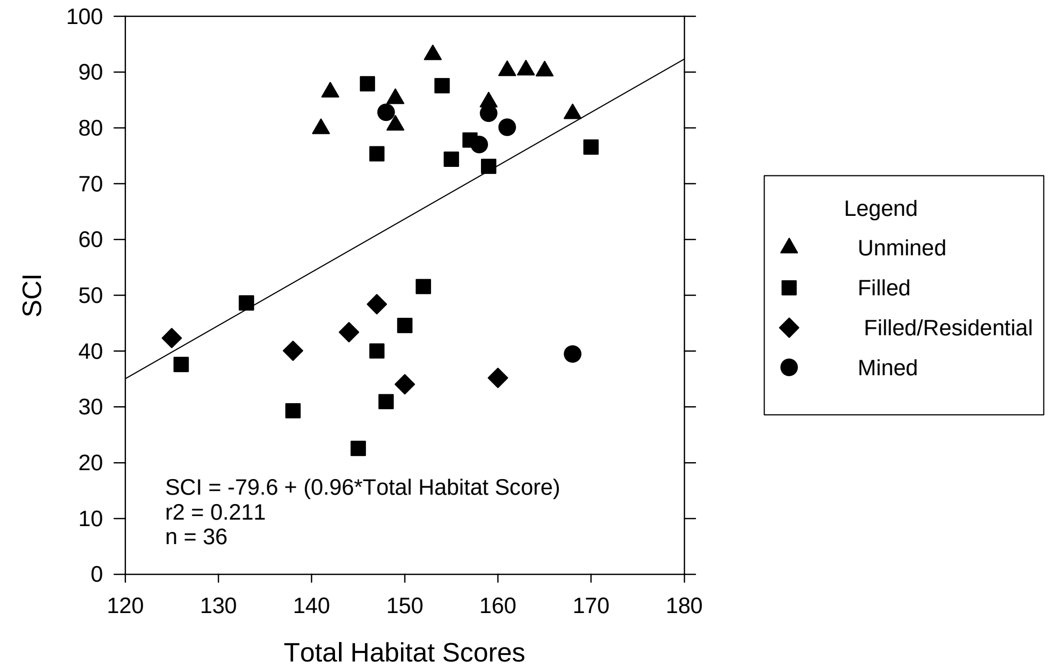

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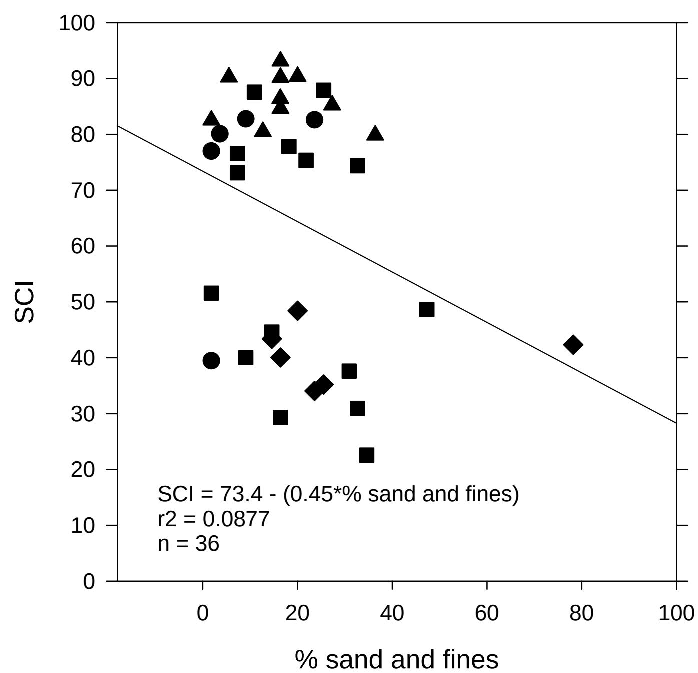

APPENDIX 5. REPLICATE DATA

Replicate samples were collected at the same place, at the same time, usually at adjacent locations in the same riffle. Replicates were collected in every season, at a total of 42 sites. Sites were chosen randomly and represent all classes and conditions of streams. The replicate samples provide an estimate of variability due to true spatial variation of the benthic assemblage within a site, and variation due to sampling and laboratory procedures. The replicate samples are highly correlated to each other for every metric used in this project (see table 4-1).

Replicate Sample Analysis
Pearson Product Moment Correlation

Metric	Correlation Coefficient r	P value
WVSCI	0.941	2.22E-20
Total Taxa	0.768	2.86E-9
EPT Taxa	0.798	2.48E-10
%EPT	0.921	6.24E-18
HBI	0.860	2.92E-13
% 2 Dominant	0.838	4.27E-12
%Chironomidae	0.902	3.74E-16
% Mayfly	0.967	2.61E-25
# Mayfly	0.831	9.83E-12

We also estimated the standard deviation of repeated measures, as suggested in the revised RBP protocol (Barbour et al 1999). The standard deviation was calculated as the root mean square error (RMSE) of an Analysis of Variance (ANOVA), where the sites are treatments in the ANOVA (see table below). These standard deviations can be used to estimate the detectable difference of a single sample from a threshold. Although comparing single samples to thresholds was not an objective of this study, the standard deviations do provide an estimate of the variability of our assessment technique.

Replicate Sample Analysis Statistics of Repeated Samples for the MTM/VF Region and the detectable difference at 0.1 significance level. Sampling Gear was a 0.5 meter wide, 595 um kick net. The WV SCI Score is on a 100 point scale. The data are at family level.		
Metric	**Standard Deviation for Repeated Measures (RMSE)**	**Detectable Difference for a single sample from a threshold (1-tailed test) (p=0.10)**
Total Taxa	2.2	2.8
EPT Taxa	1.6	2.0
HBI	0.42	0.54
% Two Dominant Taxa	5.7	7.3
% Chironomidae	6.6	8.4
% EPT	6.9	8.8
WV SCI	4.3	5.5
% Mayfly	3.2	4.1
# Mayfly Taxa	0.7	0.9

APPENDIX 6. DOCUMENTATION OF THE DROUGHT

The region of MTM/VF coal mining in WV suffered periods of prolonged dryness and drought in 1998 and 1999. West Virginia was relatively dry in July and August of 1998. Although rains occurred in September, soil moisture levels remained low. By September 1998, the National Drought Mitigation Center (NDMC) classified the state as an area to watch as far as drought concern (NDMC 1998). Stream flows remained normal throughout July and August, but were below normal in September (USGS 1998). There was not enough rainfall in October or November to improve soil moistures. In November, the state received only 45% of its normal rainfall (NDMC 1999a). The NDMC classified WV as "experiencing dryness" during October and as "experiencing significant dryness" for November and December (NDMC 1998). In December the USGS reported below normal stream flows October, November, and December (USGS 1999). By the end of December, southern portions of the state received temporary relief in the form of above normal amounts of precipitation (NDMC 1999a).

During the first month of 1999, WV received 167% of normal precipitation, but additional moisture was needed to overcome long-term shortages (NDMC 1999a). Stream flows in January were normal for southern and eastern portions of the state and were above normal for northern areas. Stream flows were reported as below normal for most of the state during February, but were reported as normal during March 1999 (USGS 1999). Stream flows for April are of particular interest since the first round of USEPA MTM biological samples were collected during April and early May. Unfortunately the USGS National Water Conditions' stream flow map for April 1999 was absent from the USGS National Water Conditions Internet site.

Rainfall amounts, for most of WV, were below normal in May, June, and July of 1999 (NDMC 1999b). The NDMC classified all of WV as an "area to watch" in May, an "area experiencing significant dryness" for June, and a "state or federally declared drought" for July, August, and September of 1999 (NDMC 1999a). USGS stream flows for the entire state, were below normal for the entire state during May, June, and July (USGS 1999). USEPA MTM biological samples were collected from July 26 – August 11. The Palmer Index of drought severity described the climate divisions that included the sampling sites as "severe drought" during these weeks. The NDMC pulled the following statement from the National Weather Service's WV Drought Statement from July 29, 1999: "The USGS reports that 80% of the river gages that have a 30 or more year record are below-normal flow for this time of year. . . Many small streams remain dry or flowing at a trickle. . . Most farm ponds remained very low or nearly dry" (NDMC 1999a).

The southwestern portion of WV continued to be classified as experiencing a drought by the US drought monitor in October, November, and December 1999 (NDMC 1999b). Most of the USGS gauges in WV continued to record below average flows during August, September, and November. Gages in the region of major mountaintop mining (MTM) activity in WV (Fedorko and Blake 1998) continued to have below average stream flows during December 1999 (USGS 1999).

On January 12, 2000 the National Weather Service (NWS) reported that drought conditions had eased for much of WV, southeast OH, eastern KY, and southwest VA. The NWS described a decrease in rainfall deficits and indicated that the Palmer Index classified the same area at normal conditions. Only 20% of the river gages in WV were reporting below normal flow, but groundwater levels were still a concern (NWS Charleston, WV 2000). Gages in the MTM region in WV continued to have below average stream flows during January, but USGS reported normal stream flows for all gages in WV during February (USGS 2000).

Throughout Spring 2000 stream flows fluctuated between normal and below normal. The USGS reported below normal stream flow for most of WV during March and May and reported normal stream flow during April and June (USGS 2000). The Long-term Palmer Index calculations for April 1, April 11, and May 13 suggested that eastern portions of the MTM region in WV were experiencing moderate drought conditions. However, the index suggested that conditions were near normal on April, 8, April 22, April 29, and May 6 (CPC 2000). The U.S. Drought Monitor continued to classify all or portions of the MTM region as "abnormally dry" throughout Spring 2000. This abnormally dry classification is used to describe areas "going into drought: short-term dryness slowing planting and growing crops or pastures; fire risk above average" and areas that are, "Coming out of drought: lingering water deficits; pastures or crops not fully recovered" (U.S. Drought Monitor 2000). Similarly, the National Drought Mitigation Center continued to classify southwestern WV as either a "drought watch area" or as an area "recovering from drought, but should be monitored closely for recurring conditions or lingering impacts" from February through May (NDMC 2000).

It is important to acknowledge that most of the drought data available at this time has been released as provisional data subject to review and that the data are aggregated spatially and temporally. In some cases the areal units are larger than the region of mountaintop mining activity in WV. However, the drought seems to have impacted a large region over several months rather than isolated locations and times. Different aggregations of the data are likely to show the same trends.

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Prepared in cooperation with the
WEST VIRGINIA DEPARTMENT OF ENVIRONMENTAL PROTECTION,
OFFICE OF MINING AND RECLAMATION

Reconnaissance of Stream Geomorphology, Low Streamflow, and Stream Temperature in the Mountaintop Coal-Mining Region, Southern West Virginia, 1999-2000

Water-Resources Investigations Report 01-4092

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Charleston, West Virginia
2001

U.S. Department of the Interior
GALE A. NORTON, Secretary

U.S. Geological Survey
Charles G. Groat, Director

For additional information write to:
District Chief
U.S. Geological Survey
11 Dunbar Street
Charleston, WV 25301

or visit our site on the World Wide Web at
http://wv.usgs.gov

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To Obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
acre	4,047	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
acre-foot (acre-ft)	1,233	cubic meters (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/ km^2]

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

°C = (°F –32) / 1.8

VERTICAL DATUM

Sea Level: In this report “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment for the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Reconnaissance of Stream Geomorphology, Low Streamflow, and Stream Temperature in the Mountaintop Coal-Mining Region, Southern West Virginia, 1999-2000

By Jeffrey B. Wiley, Ronald D. Evaldi, James H. Eychaner, and Douglas B. Chambers

Abstract

The effects of mountaintop removal coal mining and the valley fills created by this mining method in southern West Virginia were investigated by comparing data collected at valley-fill, mined, and unmined sites. Bed material downstream of valley-fill sites had a greater number of particles less than 2 millimeters and a smaller median particle size than the mined and unmined sites. At the 84th percentile of sampled data, however, bed material at each site type had about the same size particles.

Bankfull cross-sectional areas at a riffle section were approximately equal at valley-fill and unmined sites, but not enough time has passed and insufficient streamflows since the land was disturbed may have prevented the stream channel at valley-fill sites from reaching equilibrium. The 90-percent flow durations at valley-fill sites generally were 6-7 times greater than at unmined sites. Some valley-fill sites, however, exhibited streamflows similar to unmined sites, and some unmined sites exhibited streamflows similar to valley-fill sites. Daily streamflows from valley-fill sites generally are greater than daily streamflows from unmined sites during periods of low streamflow. Valley-fill sites have a greater percentage of baseflow and a lower percentage of flow from storm runoff than unmined sites. Water temperatures from a valley-fill site exhibited lower daily fluctuations and seasonal variations than water temperatures from an unmined site.

INTRODUCTION

Increased mechanization of coal mining in West Virginia in recent decades has led to wider-scale use of mountaintop-mining techniques to reach coal seams and the use of valleys to dispose of excess materials, creating what is known as “valley fills.” Mountaintop mining with valley fills in the coal-mining region, southern West Virginia, has changed forested landscapes with layered sedimentary rocks into grass-covered landscapes containing poorly sorted rock fragments with large interconnected spaces. The U.S. Geological Survey (USGS), in cooperation with the West Virginia Department of Environmental Protection, Office of Mining and Reclamation, investigated the stream geomorphology and measured the low streamflow and stream temperature from mined and unmined areas to determine the effects of valley fills upon streams.

Results of this study will be used to prepare the Mountaintop Mining/Valley Fill Environmental Impact Statement (EIS). The Mountaintop Mining/Valley Fill EIS will assess the policies, guidance, and decision-making processes of regulatory agencies in order to minimize any adverse environmental effects from this mining practice. Preparation of the EIS is a voluntary effort among the Office of Surface Mining, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, U.S. Fish and Wildlife, and the West Virginia Department of Environmental Protection (U.S. Environmental Protection Agency, 2001).

This report presents comparisons of streambed materials, stream-channel characteristics, low streamflow, and stream temperature among sites with and without valley fills. A comparison of streambed materials can indicate habitat alteration for stream aquatic organisms if the particle-size distribution shows an appreciable change in the number of small particles. A comparison of stream-channel characteristics can indicate an increase in peak discharges if bankfull area, width, and depth increase. A comparison of stream temperature can indicate possible effects to stream aquatic organisms if the magnitude of annual fluctuations are reduced. A comparison of low streamflow can indicate changes in water quantity and alterations in habitat that can affect the stream aquatic communities. The study area is in the southern coalfields of West Virginia, and results of this study may apply to other areas along the Appalachian Mountains and worldwide with similar geohydrology.

Description of study area

The study area is in the Appalachian Plateaus Physiographic Province of southern West Virginia (fig. 1). It consists of consolidated, mostly noncarbonate sedimentary rocks that dip gently to the northwest. Streams have eroded the rocks forming steep hills with deeply incised valleys that follow a dendritic pattern and have formed uplifted plateaus because of resistant layers of sandstone and shale (Fenneman, 1938; Fenneman and Johnson, 1946; and U.S. Geological Survey, 1970). Most ground water flows primarily in bedding-plane separations beneath valley floors and in slump fractures along the valley walls (Wyrick and Borchers, 1981). Generally, ground-water movement is greater laterally than vertically and decreases with increasing depth to about 100 ft, except in coal seams where equivalent ground water can move at depths greater than 200 feet (Harlow and LeCain, 1993). The climate is primarily continental, with mild summers and cold winters (U.S. Geological Survey, 1991). Mean annual precipitation is about 44 in. (U.S. Department of Commerce, 1960), and a 24-hour precipitation intensity of about 2.75 in. falls on the average of once every two years (U.S. Department of Commerce, 1961).

Background

The demand for low-sulfur coal increased during the 1990s partly because of efforts to reduce harmful emissions from coal-fired power plants. This increase and the application of dragline mining technologies made it economical to extract low-sulfur coal from the southern coalfields of West Virginia. The draglines remove large quantities of material atop and between the low-sulfur coal seams and deposit the material in adjacent valleys. The number of mines using dragline methods has increased affecting the environment. These effects include alterations in streambed material, stream-channel characteristics, low streamflow, and stream temperature.

Many of the changes in the stream environment that potentially result from mountaintop mining affect biological communities in these streams. Changes in sediment transport and deposition, streamflows, and temperature alter the physical and chemical environment to which biological communities are adapted.

Deposition of fine-grained sediment often alters the physical habitat of streams. Changes in the physical habitat used for feeding, reproduction, and cover affect biological communities. Although all stream communities may be affected by habitat change caused by sedimentation, effects to benthic invertebrate and fish communities have been studied most extensively.

Increases in transport and deposition of fine sediments decreases the abundance of invertebrates and invertebrate species (Lemly, 1982; Nutall, 1972). Some taxa, such as the Heptageniid mayfly *Epeorus pleuralis*, prefer a habitat underneath large rocks in cobble substrates. Filling of the spaces underneath the large rocks by fine sediments reduces the availability of this habitat (Minshall, 1967). Some invertebrates are displaced by the loss of this habitat, and other invertebrates must modify behaviors making them more susceptible to predation (Haro and Brusven, 1994). Sedimentation can decrease flow through the stream substrate, decreasing the availability of the stream-substrate habitat, an important refuge for invertebrates during droughts (Richards and Bacon, 1994). Sedimentation can reduce invertebrate feeding efficiency. Malas and Wallace (1977) found that sediments can clog the finely meshed capture nets of the filter feeding caddisfly *Dolophilodes modesta*. Furthermore, sedimentation can reduce the quality of food resources for the benthic community (Graham, 1990).

Sedimentation can reduce or eliminate the abundance of fish and fish species because of the sedimentation effects on the invertebrate communities. Particular fish species that feed upon benthic macroinvertebrates and periphyton may be reduced or eliminated because sedimentation reduces their food sources (Berkman and Rabeni, 1987). Berkman and Rabeni also found that particular fish species requiring clean stony or gravel substrates for spawning may be reduced or elim-

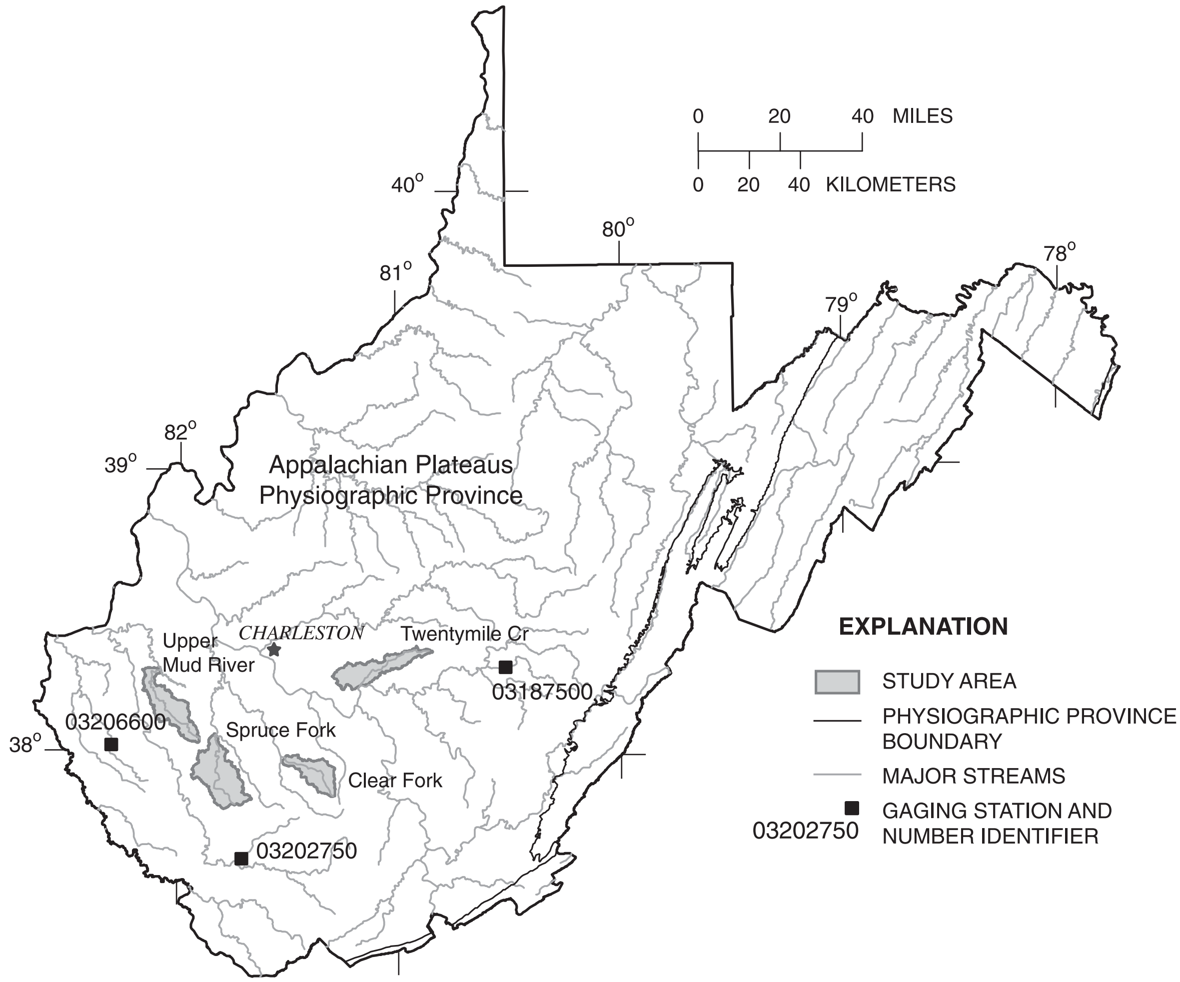

Figure 1. Location of study basins and long-term gaging stations in the coal-mining region of southern West Virginia.

inated because of increased sedimentation. Furthermore, sedimentation can eliminate or reduce deep pool habitats, a habitat providing cooler waters with increased stream depth during summer months (Waters, 1995).

Increases in 90-percent flow duration, the flow that is exceeded 90-percent of the time, and baseflow, the portion of flow the stream receives from ground water, at valley-fill sites can affect benthic invertebrate communities. Streams with valley fills may flow throughout the drought season, although before mining, no-flow periods may have been common. During droughts, invertebrates utilize various drought-survival strategies enabling them to persist until streamflows return (Feminella, 1996; Dietrich and Anderson, 2000). The effects to benthic communities of subtle alterations in streamflow are uncertain because, other than flood or drought effects, little attention has been given to studying the effect of changing streamflow in stream ecology. Increases in baseflow from valley fills can be beneficial because of increases in water availability and waste assimilation. However, increases in baseflow from valley fills can be detrimental because streamflows originating from valley fills can have higher specific conductance than streamflows originating from other settings (Green and others, 2000); thus, eliminating some sensitive species and reducing numbers of tolerant species (Green and others, 2000).

Water temperature affects all aspects of aquatic invertebrate physiology and ecology (Allan, 1995). Timing of crucial life-cycle events such as egg hatching, emergence, and mating relies on thermal cues

(Ward and Stanford, 1982). Temperature controls the growth rate of most species, and interactions among closely related species may be reduced because different responses to temperature segregate the species in time (Ward and Stanford, 1982). Temperature controls the feeding efficiency of invertebrate species along a thermal gradient such that the optimal temperature for assimilation of food often determines the distribution of invertebrate species. Furthermore, temperature changes can increase or decrease algal food production, thereby affecting all higher levels in the food chain (Ward and Stanford, 1982). The annual range of temperatures can also affect the invertebrate communities. An increase in the annual range of temperature, within limits, can increase the number of invertebrates species and the abundance of many species in a stream. A decrease in the annual range of temperature, whether from natural or human factors, can decrease the number of species in a stream (Ward and Stanford, 1982).

DATA COLLECTION

Stream geomorphology and low streamflow measurements were made at a network of 54 small stream sites with drainage areas of 26 to 1,527 acres (fig. 2). The 54 sites were chosen from a larger group of about 120 sites with similar drainage areas. A team of agencies determined the 120 sites as sample locations. The 120 sites were located in five basins, and the sites had an identified land use of either unmined, mined, or valley fill. Unmined sites were those with no evidence of previous coal mining in the tributary watersheds. Mined sites represent watersheds where coal has been mined but where no valley fills were constructed. Valley-fill sites were in tributary watersheds where both previous mining and valley fills were present. In general, the valley-fill sites represent recent or larger mining operations, and the mined sites represent older or smaller operations.

Two sites (station numbers MT67 and MT68B) were combined to make one of the 54 sites because particle size could not be measured on the individual stream reaches (fig. 2b). The subset of 54 sites was selected throughout four of the five basins where the USGS had active short-term (data collected for less than 10 years) streamflow-gaging stations: Unnamed Tributary to Ballard Fork near Mud (03204205), Spring Branch near Mud (03204210), and Ballard Fork near Mud (03204215) in the Upper (upstream of Middle Fork) Mud River Basin, (fig. 2a); Clear Fork at Whitesville (03198350) in the Clear Fork Basin (fig. 2b); Twentymile Creek at Vaughan (03192200) in the Twentymile Creek Basin (fig. 2c); and, Spruce Fork at Sharples (03198690) in the Spruce Fork Basin (fig. 2d).

Continuous streamflow and stream temperature were measured at two USGS streamflow-gaging stations in the Upper Mud River Basin, Unnamed Tributary to Ballard Fork near Mud (03204205) and Spring Branch near Mud (03204210). Continuous data are collected at time intervals that accurately represent the changes among individual values. Continuous streamflow data were collected at three long-term (data collected for ten years or longer) USGS gaging stations (fig. 1): Cranberry River near Richwood (03187500), Clear Fork at Clear Fork (03202750), and East Fork Twelvepole Creek near Dunlow (03206600).

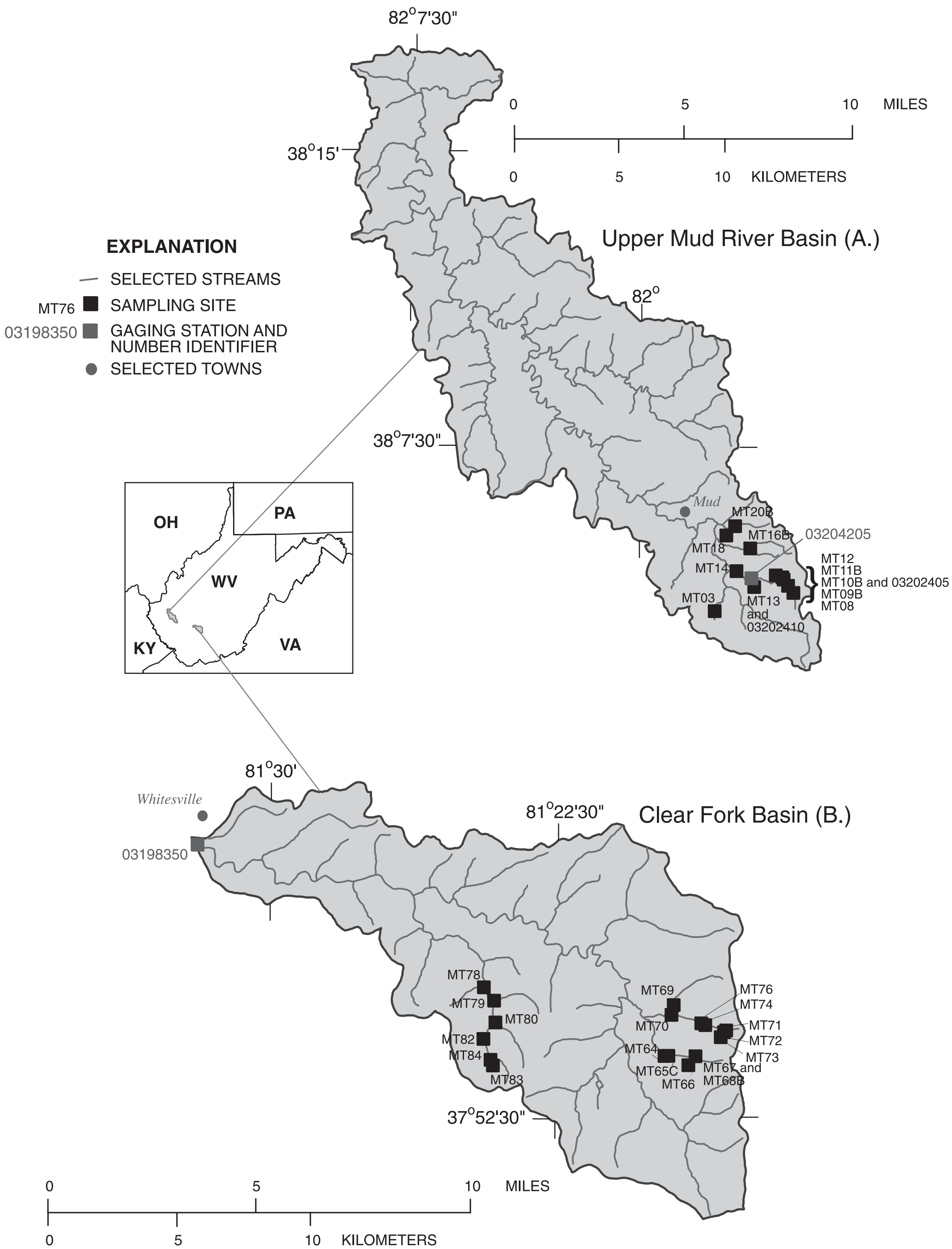

Figure 2A-B. Upper Mud River Basin (A.), Clear Fork Basin (B.), short-term gaging stations, and small-stream sampling sites in the coal-mining region of southern West Virginia.

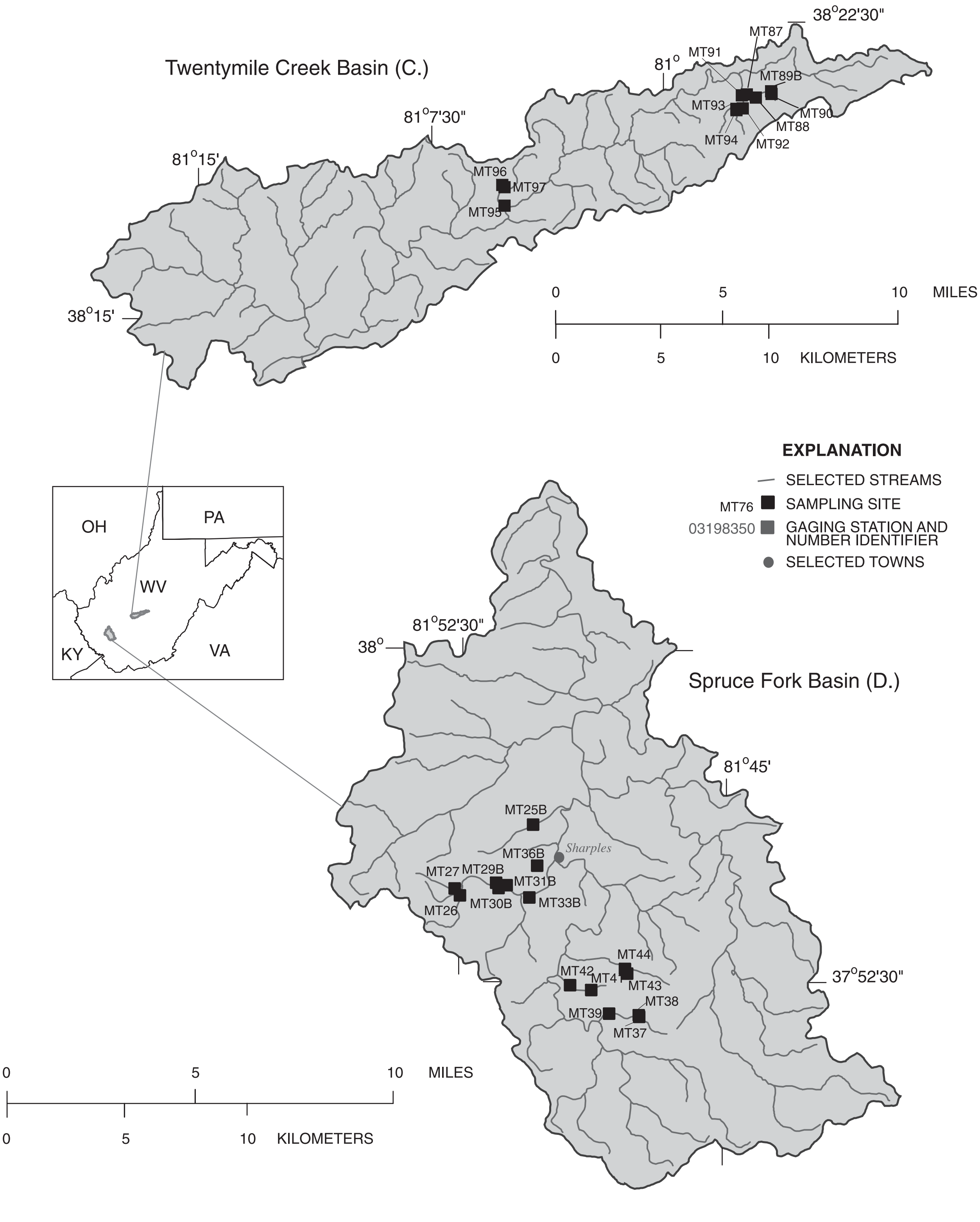

Figure 2C-D. Twentymile Creek Basin (C.), Spruce Fork Basin (D.), short term gaging stations, and small-stream sampling sites in the coal-mining region of southern West Virginia.

Geomorphology

Bed material and bankfull channel characteristics were measured at the 54 sites in the Clear Fork, Upper Mud River, Spruce Fork, and Twentymile Creek Basins (fig. 2). Bankfull is the stream stage and discharge that forms the stream channel. Bankfull discharge transports the maximum amount of sediments over time resulting in bankfull-channel characteristics representative of the watershed (Rosgen, 1996).

Methods described by Wolman (1954) were modified and used to make a quantitative analysis of the distribution of particle sizes on the streambed in this study. The method required measuring the size of up to 100 particles from each stream. Collecting particle-size information from multiple cross sections with a mixture of geomorphic features (such as riffles, pools, and runs) was desired, but at some sites a pool-and-riffle pattern was not available or the streams were too narrow (less than 10 ft). The method presented by Wolman, therefore, was modified to collect pebbles from a mixture of geomorphic features on narrow streams. Streambed-particle sizes were surveyed between October 25 and November 10, 1999 (table 4, located at the end of this report) using the following method:

(1) Begin the pebble count at bankfull elevation on the left bank at the upstream boundary of the stream reach and proceed downstream toward the right bank. Proceed at a 45-degree angle (or less for short reaches) with a line along the center of streamflow (or center of channel if the center of streamflow is not apparent) to the bankfull elevation on the right bank. Proceed downstream from right bank to left bank and left bank to right bank until 60-100 pebbles are collected or until arriving at the end of the stream reach.

(2) Proceed one step at a time, with each step constituting a sampling point.

(3) At each step, reach down to the tip of your boot and, with your finger extended, pick up the first pebble touched by the extended finger;

(4) To reduce sampling bias, look across and not down at the channel bottom when taking steps or retrieving bed material; and,

(5) As you retrieve each pebble, measure the intermediate axis. If the intermediate axis cannot be determined easily, measure the long diameter and the short diameter of the pebble, and determine the average of the two numbers.

Bankfull channel characteristics were surveyed between August 31 and November 9, 2000 (table 4). A cross section was selected in a riffle where effects of exceptional features such as a large (relative to the stream size) rock, cliff, or fallen tree were minimal. The bankfull channel was located using techniques that include identifying bankfull indicators such as changes in bank slope, vegetation, and sediments. The maximum depth, width, and cross-sectional area of the bankfull channel were determined.

Low streamflow measurements

Discharges at the 54 sites in the Clear Fork, Upper Mud River, Spruce Fork, and Twentymile Creek Basins (fig. 2) were measured four times during low streamflow (table 5, located at the end of this report) using methods described by Rantz and others, 1982. The four measurement periods were October 25 through November 10, 1999; June 6-9, 2000; August 16-21, 2000; and August 31 through November 9, 2000.

Continuous streamflow and stream temperature

The USGS collects continuous streamflow data at selected locations, provides historic and real-time data at http://www.usgs.gov/ (real-time data are not available for all stations), and publishes data annually (see for example, Ward and others, 2000). Continuous streamflow data are collected following procedures described by Rantz and others, 1982. Streamflow data were collected at two gaging stations where temperature data also were collected. Streamflow data necessary to determine reliable low streamflow statistics for this study required a minimum of 10 years of unregulated continuous record. Data from continuous streamflow-gaging stations with drainage areas approximately equal to those of the 54 sites was preferred, but no stations were available with 10 years of record in the current network of gages with drainage areas as small as the 54 sites. Streamflow-gaging stations in the study area at the time of this study (1999-2000) that had been operating for a minimum of 10 years drained much greater areas: Cranberry River near Richwood (03187500), 80.4 mi^2; Clear Fork at Clear Fork (03202750), 126 mi^2; and, East Fork Twelvepole Creek near Dunlow (03206600), 38.5 mi^2.

Continuous stream temperature was measured at two USGS streamflow-gaging stations established in Ballard Fork of the Upper Mud River Basin in November 1999. The two stations are located near two of the 54 sites (fig. 2a). The station Unnamed Tributary to Ballard Fork near Mud (03202405) is near sample site MT10B, about 400 feet downstream of a valley fill. The station Spring Branch near Mud (03202410) is near sample site MT13, which drains an unmined basin. Installation of the temperature monitors followed manufacturer specifications and procedures described by Wilde and others (1998).

STREAM GEOMORPHOLOGY

Stream geomorphology was analyzed using measurements of bed materials and channel characteristics. Stream geomorphology for unmined, mined, and valley-fill sites are compared.

Bed material

Bed material data were studied using particle sizes of the median, 84^{th} percentile, and percentage less than 2 millimeters. The 84^{th} percentile is an arbitrary particle size equal to two standard deviations larger than the mean size, assuming a normal distribution. The particle size of the 84^{th} percentile has been related to stream roughness, and particles greater than or equal to the 84^{th} percentile can be considered as large particles (Leopold and others, 1995). Particle sizes less than 2 millimeters can be considered as small.

The distribution (median, 84^{th} percentile, and percentage of particles less than 2 millimeters) of particle sizes among unmined sites located within an individual basin are similar (table 4). The distribution of particle sizes for unmined sites among all basins, however, may or may not be similar. Particle sizes from streams draining unmined areas in Spruce Fork and Clear Fork have a similar distribution, but these particle-size distributions are different from those of streams draining unmined areas of both Upper Mud River and Twentymile Creek. The similar and dissimilar particle-size distributions among basins indicate that natural factors, such as localized geology and land slope, may have some affect on particle sizes.

The bed material of mined and unmined sites can have similar distributions of particle sizes when the land surface of the mined site is not appreciably disturbed, and the bed material of mined and valley-fill sites have similar distributions of particle sizes when the land surface of the mined site is disturbed. For example, streams at sites MT82, MT83, and MT84 (table 4), located on and tributary to Sycamore Creek in the Clear Fork Basin, drain areas of approximately the same size. The land upstream of MT82 and MT84 is mined. The land upstream of MT83 is unmined. The percentage of particles less than 2 millimeters at site MT82 (mined) is about three times the percentage of particles less than 2 millimeters at site MT83 (unmined). Additionally, the median particle size at site MT82 (mined) is about 100 millimeters smaller than the median particle size for site MT83 (unmined). Particle-size distributions at the mined site MT84, however, are similar to those at the unmined site.

Data for Spruce Fork and Clear Fork were combined on the basis of the assumption that the similar distributions of particle sizes between the basins indicated that the same natural factors, such as localized geology and land slope, were affecting the basins. The combined basins provided 8 unmined sites, 8 mined sites, and 14 valley-fill sites for further analysis. The minimum, 75^{th} percentile, median, 25^{th} percentile, and maximum particle sizes with outliers indicated as horizontal lines are shown in box plots (fig. 3). Particle sizes less than 2 millimeters are analyzed as equal to 2 millimeters. Valley-fill sites have a greater number of particles less than 2 millimeters, a smaller median particle size (11 sites out of the total 14 sites have median particle sizes less than 2 millimeters), and about the same 84^{th}-percentile particle size as the mined and unmined sites (fig. 3). The percentage of particle sizes less than 2 millimeters increases appreciably at the valley-fill sites compared to the mined and unmined sites.

Data for Upper Mud River and Twentymile Creek were insufficient for analysis similar to that done with the combination of Spruce Fork and Clear Fork data. There are a sufficient number of valley fill sites (8) in the Upper Mud River Basin, but there are no mined sites and only three unmined sites. A sufficient number of unmined sites (7) are available in the Twentymile Creek Basin, but only one mined site and three valley-fill sites are available.

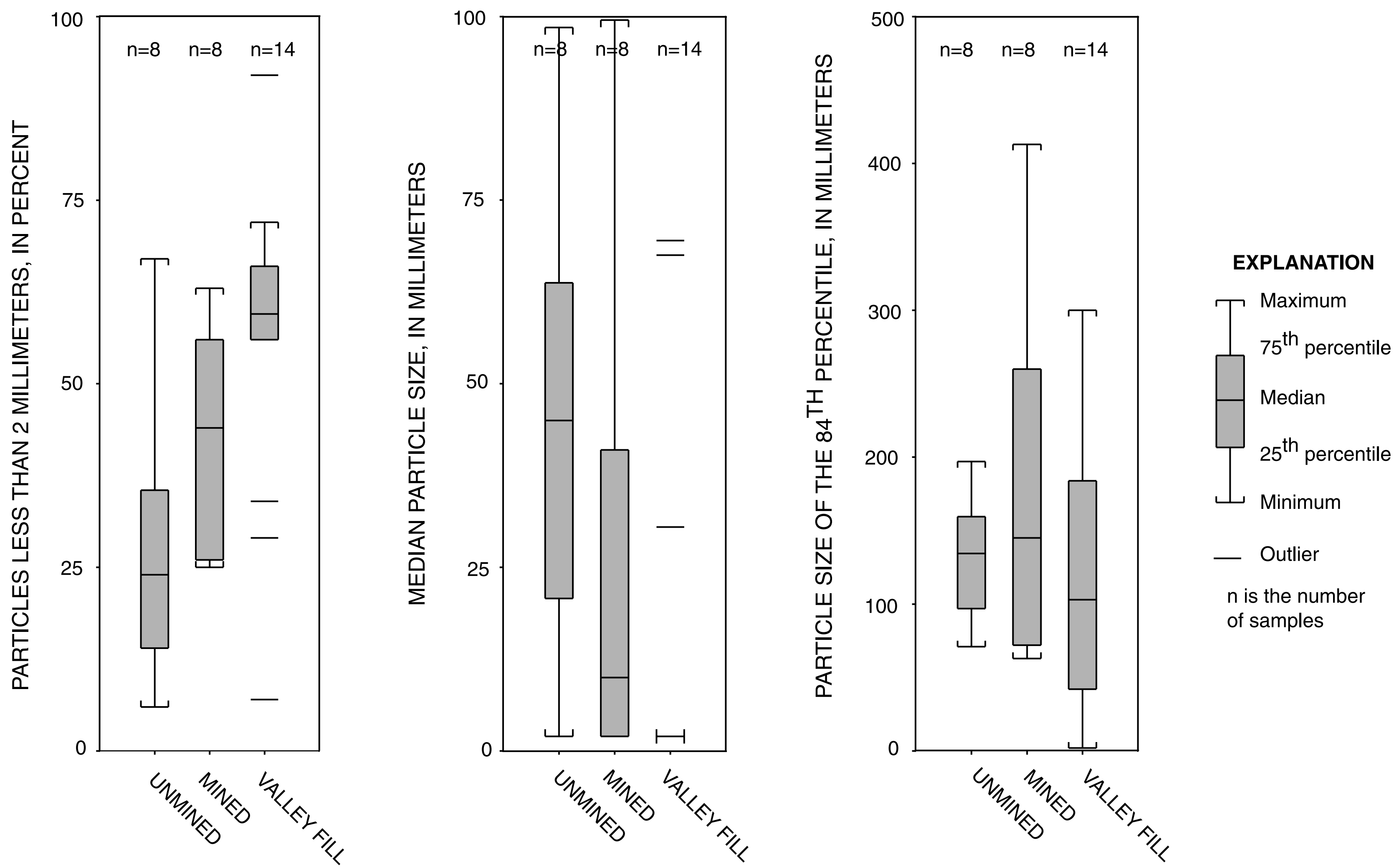

Figure 3. Distributions of particles less than 2 millimeters, median particle size, and particle size of the 84th percentile, Spruce Fork and Clear Fork Basins in the coal-mining region of southern West Virginia.

Sites with an increase in the percentage of particles less than 2 millimeters could return to the particle-size distributions that were present before the land disturbance. A sediment-load study (Ward and Appel, 1988) in relation to highway construction in southern West Virginia indicated that sediment loads decreased after revegetation and stabilization of the disturbed land. The report also indicated a trend of decreasing magnitudes of sediment loads, but the time required for the sediment loads to return to magnitudes of the pre-construction loads was not measured. Particle-size distributions measured in this study could follow a similar trend as the decreasing sediment loads in the previous report and return to the pre-disturbed distributions.

Channel characteristics

The maximum depth, width, and cross-sectional area of the bankfull channel at a riffle section were compared among valley-fill and unmined sites. Mined sites were not considered in this analysis because there were only nine, which is an insufficient number of sites to develop a regression curve. Comparisons among maximum depths, maximum widths, and drainage areas did not indicate any difference between valley-fill and unmined sites. Comparisons among cross-sectional areas and drainage areas (fig. 4) show the similarity between the valley-fill and unmined sites. The linear regression equation for the valley-fill sites (R-squared = 0.48; standard error = 47 percent) is

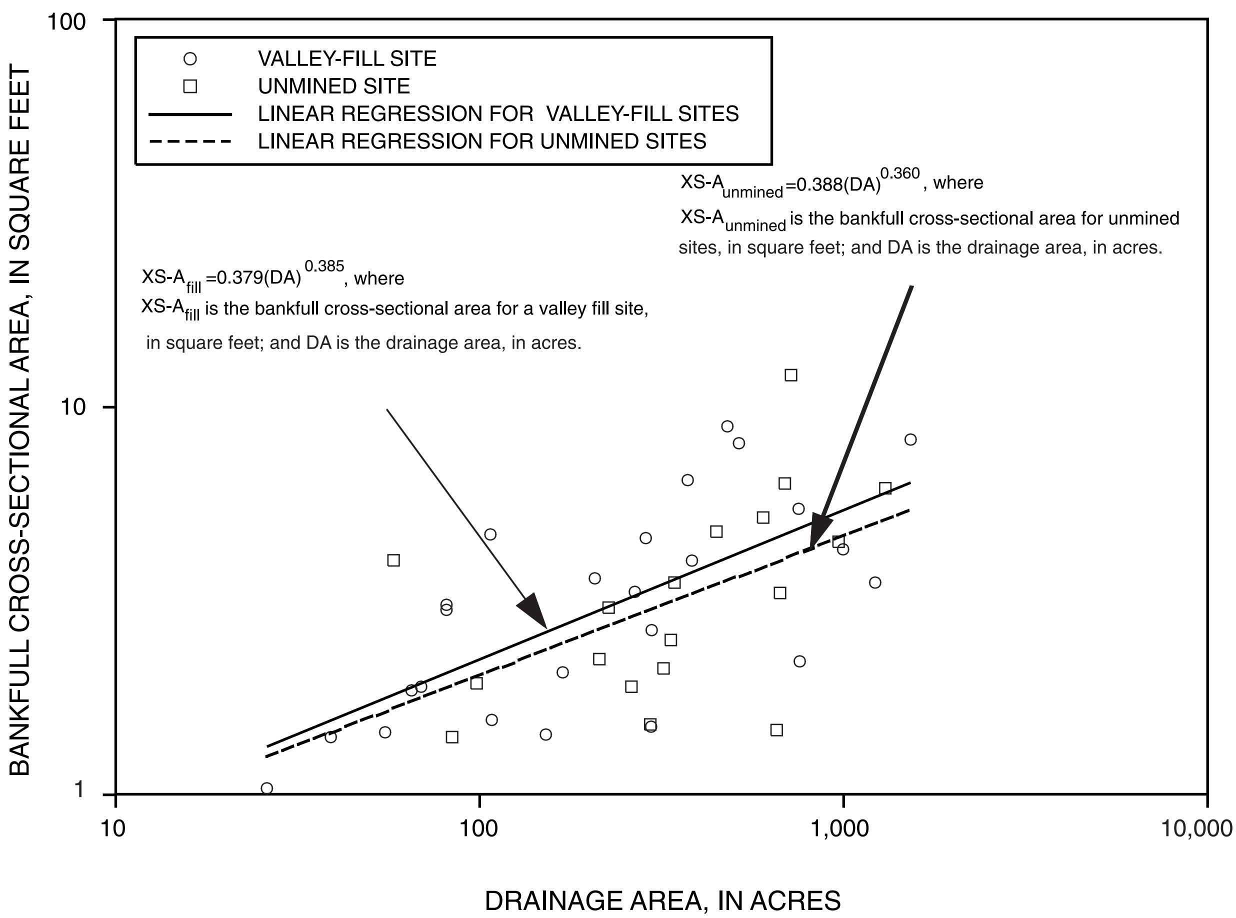

Figure 4. Comparisons among bankfull cross-sectional areas and drainage areas for valley-fill and unmined sites in the coal-mining region of southern West Virginia.

$$XS\text{-}A_{fill} = 0.379\,(DA)^{0.385},$$

where

$XS\text{-}A_{fill}$ is the bankfull cross-sectional area for a valley-fill site, in square feet;

and

DA is the drainage area, in acres.

The linear regression equation for the unmined sites (R-squared = 0.27; standard error = 54 percent) is

$$XS\text{-}A_{unmined} = 0.388\,(DA)^{0.360},$$

where

$XS\text{-}A_{unmined}$ is the bankfull cross-sectional area for unmined sites, in square feet;

and

DA is the drainage area, in acres.

The approximately equal bankfull cross-sectional areas of valley-fill and unmined sites suggests the bankfull discharges between the two groups are approximately equal. This conclusion may be inaccurate if bankfull indicators are not representative of land-use changes. Bankfull indicators at valley-fill sites may be biased toward the pre-disturbed condition (an unmined condition) if the elapsed time and peak streamflows since the land was disturbed have been insufficient to bring the channel (thus, the bankfull indicators) to equilibrium.

LOW STREAMFLOW CHARACTERISTICS

Low streamflow characteristics were investigated by comparing 90-percent flow durations (the streamflow expected to be equalled or exceeded at the site 90 percent of the time), daily streamflow records, base-streamflows (streamflow from ground-water discharge), and stormflows (streamflow from over-land runoff) among all valley-fill and unmined sites.

Ward and others (2000) published the 90-percent flow durations for the selected continuous streamflow-gaging stations (table 1). The discharge measurements made at the 54 sites were compared to concurrent discharges at the continuous streamflow stations. These data were used to estimate the 90-percent flow duration at the 54 sites (table 4), using methods described by Riggs (1972).

Low streamflows in relation to drainage area were compared among all valley-fill and unmined sites (fig. 5). Mined sites were not considered in this analysis because only 9 sites were available, which is an insufficient number of sites to develop a regression curve. Sites with 90-percent flow durations of no streamflow were omitted (six sites), because the data were $\log_{10}$ transformed. The valley-fill sites can have about a 6-7 times greater 90-percent flow duration than unmined sites (fig. 5). The linear regression equation for the valley-fill sites (R-squared = 0.60; standard error = 115 percent) is

Table 1. Low-streamflow statistics at long-term gaging stations in the coal-mining region of southern West Virginia

Station number	Station name	90-percent flow duration, in cubic feet per second
03187500	Cranberry River near Richwood	16
03202750	Clear Fork at Clear Fork	12
03206600	East Fork Twelvepole Creek near Dunlow	1.3

$$D90_{fill} = 0.000161\ (DA)^{1.098},$$

where

$D90_{fill}$ is the 90-percent flow duration for a valley-fill site, in cubic feet per second;

and

DA is the drainage area, in acres.

The linear regression equation for the unmined sites (R-squared = 0.29; standard error = 155 percent) is

$$D90_{unmined} = 0.0000209\ (DA)^{1.129},$$

where

$D90_{unmined}$ is the 90-percent flow duration for an unmined site, in cubic feet per second; and

DA is the drainage area, in acres.

Three of the valley-fill sites (MT74, MT87, and the combination of MT67 and MT68B) exhibited 90-percent flow durations similar to those of unmined sites, and three of the unmined sites (MT41, MT92, and MT97) exhibited 90-percent flow durations similar to those of valley-fill sites (fig. 5). The site MT41 is on Oldhouse Branch in the Spruce Fork Basin. Another site on Oldhouse Branch, MT42, has a larger drainage area and smaller 90-percent flow duration than MT41. Field observations indicated some of the streamflow measurements from MT41 were made where the streambed was a rock outcrop. These measurements at the rock outcrop suggest it restricts ground-water flow, and the outcrop was forcing water to the surface into the stream. The water forced to the surface and into the stream may have produced a greater discharge than typically is at an unmined site with that drainage area. Other unmined sites that exhibit 90-percent flow durations similar to 90-percent flow durations from valley-fill sites may have similar field conditions. This conclusion, however, is speculative and not definitive.

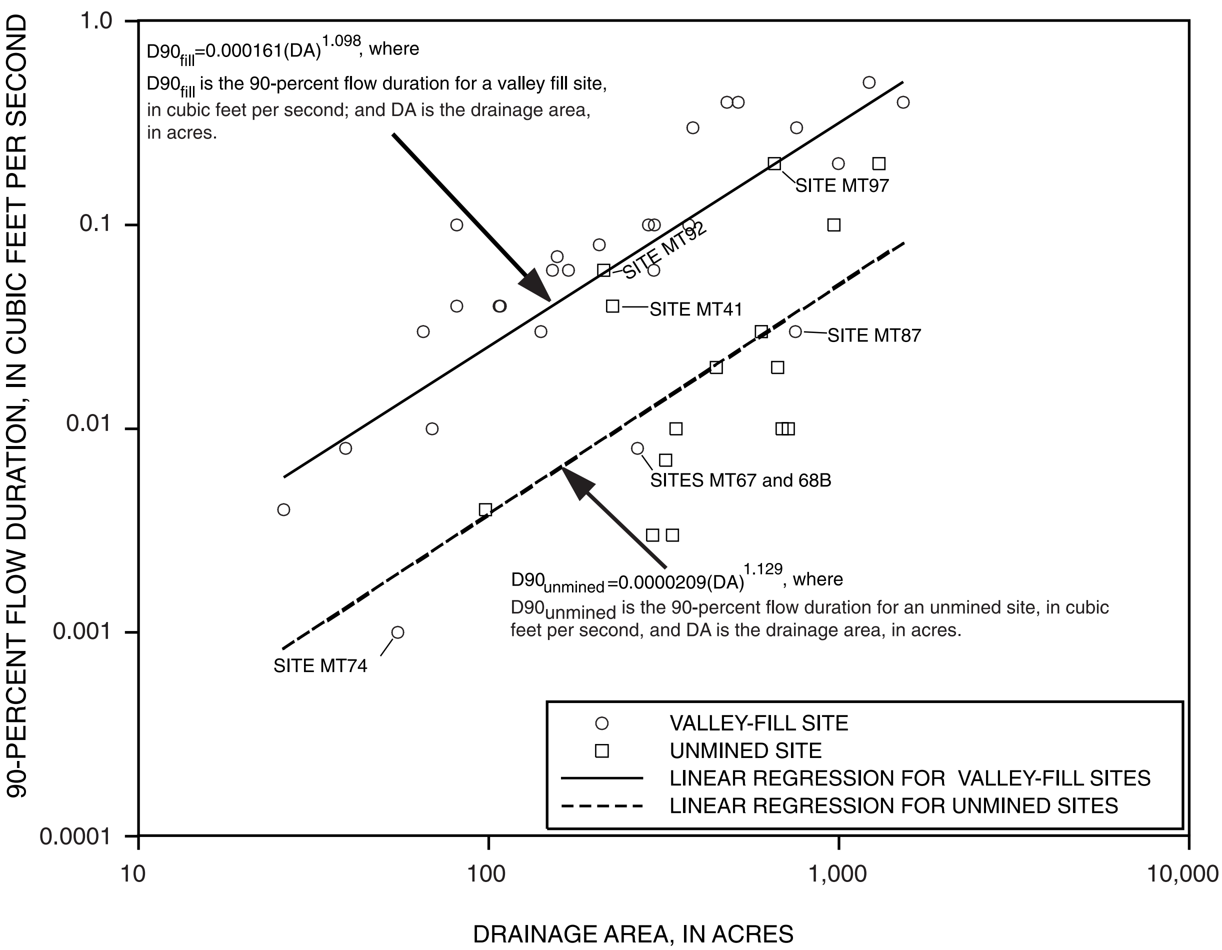

Figure 5. Comparisons among the 90-percent flow durations and drainage areas for valley-fill and unmined sites in the coal-mining region of southern West Virginia.

Valley-fill sites exhibiting 90-percent flow durations similar to unmined sites suggest the fill is not retaining water, as is typical of other fills. Water may not be retained because the fill is relatively small compared to the rest of the drainage area or because of some difference in the design of the fill, but data collected for this study are insufficient to determine a specific cause.

Daily streamflows determined for the valley-fill site, Unnamed Tributary to Ballard Fork near Mud (03202405), and the unmined site, Spring Branch near Mud (03202410), for the period December 1999 through November 2000 are presented in tables 2 and 3, respectively. Spring Branch had no streamflow for several days in October and November, but Unnamed Tributary to Ballard Fork had streamflow for the entire period. Greater streamflows may be expected at Spring Branch than at Unnamed Tributary to Ballard Fork for these days in October and November because the drainage area at Spring Branch (0.53 mi^2) is 2.8 times greater than the drainage area at Unnamed Tributary to Ballard Fork (0.19 mi^2). The most probable reason that streamflow is not greater at Spring Branch than at Unnamed Tributary to Ballard Fork is because Unnamed Tributary to Ballard Fork is a valley-fill site, and the valley-fill sites can have about a 6-7 times greater 90-percent flow duration than unmined sites (fig. 5).

The daily streamflow data from Spring Branch and Unnamed Tributary to Ballard Fork gaging stations were analyzed using a technique of streamflow partitioning. Streamflow partitioning separates streamflow data into estimates of base-streamflow and stormflow components using the Rorabaugh streamflow model (Rutledge, 1998). For this report, streamflow data were partitioned for the period December 1999 through November 2000. The estimated unit-mean base streamflow was 0.98 cubic foot per second per square mile of drainage area [$(ft^3/s)/mi^2$] for Unnamed Tributary to Ballard Fork and 0.42 $(ft^3/s)/mi^2$ for Spring Branch. Streamflows were about 84-percent base streamflow and 16-percent stormflow for Unnamed Tributary to Ballard Fork, and streamflows were about 59-percent base streamflow and 41-percent stormflow for Spring Branch. The most probable reason the unit-mean base streamflow and percentage of base streamflow are greater for Unnamed Tributary to Ballard Fork than Spring Branch is because Unnamed Tributary to Ballard Fork is a valley-fill site, and the valley-fill sites can have about a 6-7 times greater 90-percent flow duration than unmined sites (fig. 5).

STREAM TEMPERATURE

Daily water-temperature data measured at Unnamed Tributary to Ballard Fork near Mud (03202405) and at Spring Branch near Mud (03202410), for the period December 1999 through November 2000, are presented in tables 6 and 7, respectively (located at the end of this report). The temperature monitor at Unnamed Tributary to Ballard Fork is approximately 400 ft. downstream from a valley fill. The daily fluctuations of temperatures at Unnamed Tributary to Ballard Fork are less than the daily fluctuations at Spring Branch. The minimum water temperature observed at Unnamed Tributary to Ballard Fork was 3.3°C on January 28, 2000, which indicated above freezing conditions. The minimum water temperature observed at Spring Branch was –2.4°C on January 28, 2000, which probably indicated frozen water conditions. The minimum water temperatures at Unnamed Tributary to Ballard Fork and Spring Branch differ because water at Unnamed Tributary to Ballard Fork was mixed with warmer water discharging from the valley fill. The water temperature at Unnamed Tributary to Ballard Fork showed a lesser seasonal range than the seasonal range observed at Spring Branch. The daily-mean water temperature at Unnamed Tributary to Ballard Fork was greater than the daily-mean water temperature at Spring Branch during winter, and the daily-mean water temperature at Unnamed Tributary to Ballard Fork was less than the daily-mean water temperature at Spring Branch during summer (fig. 6).

Table 2. Daily mean discharges in cubic feet per second, December 1999 through November 2000, at Unnamed Tributary to Ballard Fork near Mud (03202405) in the coal-mining region of southern West Virginia

[e, estimated; --, no value; Acre-ft, quantity of water required to cover 1 acre to a depth of 1 foot; CFSM, cubic foot per second per square mile; In., depth to which the drainage area would be covered by the indicated runoff]

Day	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
1	0.27	0.26	e0.22	0.31	0.10	0.20	0.28	e0.21	0.20	0.11	0.11	0.12
2	.23	.25	e.20	.29	.10	.20	.25	e.21	.19	.12	.10	.11
3	.20	.27	e.19	.26	.12	.19	.22	e.24	.19	.11	.10	.13
4	.20	.31	e.18	.26	.32	.17	.20	e.27	.17	.13	.10	.14
5	.19	.27	e.17	.25	.37	.16	.17	e.26	.15	.13	.10	.13
6	.20	.28	e.17	.25	.31	.15	.16	e.24	.15	.12	.10	.12
7	.17	.26	e.17	.18	.26	.14	.15	.22	.17	.11	.10	.12
8	.14	.26	e.16	.15	.30	.14	.13	.21	.23	.11	.10	.09
9	.14	.25	.16	.13	.30	.13	.12	.19	.34	.11	.10	.10
10	.17	.26	.15	.11	.26	.13	.11	.28	.54	.15	.10	.10
11	.18	e.25	.17	.21	.24	.13	.11	.55	.51	.17	.10	.10
12	.17	e.24	.16	.25	.21	.11	.11	.53	.40	.19	.10	.10
13	.22	e.23	.17	.25	.19	.13	.10	.43	.33	.16	.10	.10
14	1.3	e.22	.59	.20	.18	.10	.10	.41	.26	.14	.10	.10
15	.99	e.21	.53	.17	.17	.10	.11	.52	.24	.12	.10	.09
16	.70	e.21	.42	.14	.15	.10	.10	.51	.21	.11	.10	.09
17	.52	e.21	.32	.15	.17	.10	.21	.40	.20	.11	.10	.09
18	.43	e.21	.59	.15	.19	.09	.41	.34	.19	.11	.11	.09
19	.37	e.21	e1.8	.15	.18	.10	e.41	.34	.19	.11	.11	.09
20	.34	e.21	e1.1	.16	.17	.09	e.42	.31	.18	.11	.11	.09
21	.30	e.21	.77	.20	.19	.10	e.58	.31	.17	.11	.11	.09
22	.32	e.22	.58	.21	.22	.09	e.58	.28	.15	.11	.10	.09
23	.34	e.23	.48	.18	.21	.11	e.46	.25	.15	.10	.11	.09
24	.31	e.24	.42	.16	.23	.10	e.32	.23	.15	.10	.11	.10
25	.31	e.24	.38	.13	.35	.09	e.32	.22	.15	.14	.11	.10
26	.30	e.22	.34	.13	.39	.09	e.30	.21	.15	.14	.11	.10
27	.28	e.20	.35	.12	.34	.36	e.28	.19	.15	.15	.12	.10
28	.27	e.20	.32	.14	.29	.90	e.29	.19	.15	.13	.14	.10
29	.27	e.22	.31	.13	.25	1.2	e.26	.20	.15	.11	.14	.10
30	.26	e.25	--	.11	.21	.49	e.23	.19	.14	.11	.13	.10
31	.26	e.24	--	.11	--	.34	--	.19	.13	--	.13	--
Total	10.35	7.34	11.57	5.64	6.97	6.53	7.49	9.13	6.68	3.73	3.35	3.07
Mean	.33	.24	.40	.18	.23	.21	.25	.29	.22	.12	.11	.10
Maximum	1.3	.31	1.8	.31	.39	1.2	.58	.55	.54	.19	.14	.14
Minimum	.14	.20	.15	.11	.10	.09	.10	.19	.13	.10	.10	.09
Acre-ft	21	15	23	11	14	13	15	18	13	7.4	6.6	6.1
CFSM	1.76	1.25	2.10	.96	1.22	1.11	1.31	1.55	1.13	.65	.57	.54
In.	2.03	1.44	2.27	1.10	1.36	1.28	1.47	1.79	1.31	.73	.66	.60

Total=81.85	Mean=0.22	Maximum=1.8	Minimum=0.09	Total Acre-ft=162	Total CFSM=1.18	Total In.=16.03

Table 3. Daily mean discharges in cubic feet per second, December 1999 through November 2000, at Spring Branch near Mud (03202410) in the coal-mining region of southern West Virginia

[e, estimated; --, no value; Acre-ft, quantity of water required to cover 1 acre to a depth of 1 foot; CFSM, cubic foot per second per square mile; In., depth in inches to which the drainage area would be covered by the indicated runoff]

Day	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
1	0.13	0.11	0.12	0.35	0.31	0.47	0.25	0.12	0.18	0.09	0.00	0.07
2	.13	.10	.12	.32	.31	.43	.20	.10	.15	.08	.00	.00
3	.12	.11	.13	.30	e.6	.34	.16	.13	.11	.08	.01	.01
4	.11	.18	.15	.29	e3.1	.29	.13	.17	.10	.09	.01	.02
5	.11	.14	.14	.27	e2.1	.26	.12	.13	.09	.07	.01	.05
6	.12	.14	.14	.25	e1.6	.23	.10	.11	.08	.08	.01	.07
7	.10	.14	.15	.25	e1.1	.21	.09	.09	.14	.07	.01	.02
8	.09	.14	.16	.26	e1.6	.18	.07	.07	.30	.08	.00	.00
9	.09	.17	.17	.30	e1.5	.16	.06	.07	.32	.06	.01	.03
10	.20	.18	.19	.26	e1.4	.14	.05	.35	.64	.32	.03	.08
11	.16	.17	.23	.53	e1.2	.11	.04	.87	.33	.10	.00	.03
12	.15	.15	.23	.92	e1.1	.09	.03	.44	.24	.03	.01	.02
13	.29	.14	.25	.90	e.9	.18	.03	.29	.20	.02	.02	.03
14	4.8	.12	2.2	.79	.67	.11	.04	.39	.16	.02	.03	.04
15	1.1	.12	1.4	.66	.60	.08	.11	.36	.13	.02	.00	.04
16	.54	.13	.95	.64	.53	.07	.06	.33	.12	.01	.01	.04
17	.37	.12	.62	.73	.55	.07	.29	.28	.12	.01	.01	.06
18	.29	.12	2.5	.68	.51	.06	.37	.22	.18	.01	.03	.08
19	.24	.12	e14	.68	.49	.20	.37	.36	.13	.01	.00	.10
20	.22	.13	e3.5	.74	.48	.20	.31	.36	.12	.01	.01	.10
21	.18	.11	e1.7	.95	.60	.13	1.8	.30	.12	e.01	.01	.11
22	.17	.10	e1	.94	.64	.10	6.3	.25	.11	e.01	.01	.13
23	.15	.11	.68	.89	.70	.27	1.1	.21	.11	e.01	.02	.14
24	.14	.11	.59	.76	.77	.17	.48	.20	.13	e.01	.02	.17
25	.12	.10	.49	.66	1.5	.13	.32	.17	.10	e.01	.00	.07
26	.13	.10	.41	.59	1.8	.10	.25	.14	.10	e.01	.01	.04
27	.12	.09	.43	.54	1.4	2.6	.23	.11	.14	e.01	.01	.04
28	.12	.08	.38	.49	1.0	2.0	.25	.12	.10	e.01	.01	.04
29	.11	.10	.35	.41	.76	.88	.20	.13	.09	e.01	.01	.05
30	.11	.15	--	.37	.56	.53	.16	.16	.08	e.01	.03	.08
31	.11	.13	--	.33	--	.34	--	.12	.08	--	.06	--
Total	10.82	3.91	33.38	17.05	30.38	11.13	13.97	7.15	5.00	1.36	0.40	1.76
Mean	.35	.13	1.15	.55	1.01	.36	.47	.23	.16	.045	.013	.059
Maximum	4.8	.18	14	.95	3.1	2.6	6.3	.87	.64	.32	.06	.17
Minimum	.09	.08	.12	.25	.31	.06	.03	.07	.08	.01	.00	.00
Acre-ft	21	7.8	66	34	60	22	28	14	9.9	2.7	.8	3.5
CFSM	.66	.24	2.17	1.04	1.91	.68	.88	.44	.30	.09	.02	.11
In.	.76	.27	2.34	1.20	2.13	.78	.98	.50	.35	.10	.03	.12

Total=136.31 Mean=0.37 Maximum=14 Minimum=0.00 Total Acre-ft=270 Total CFSM=0.70 Total In.=9.57

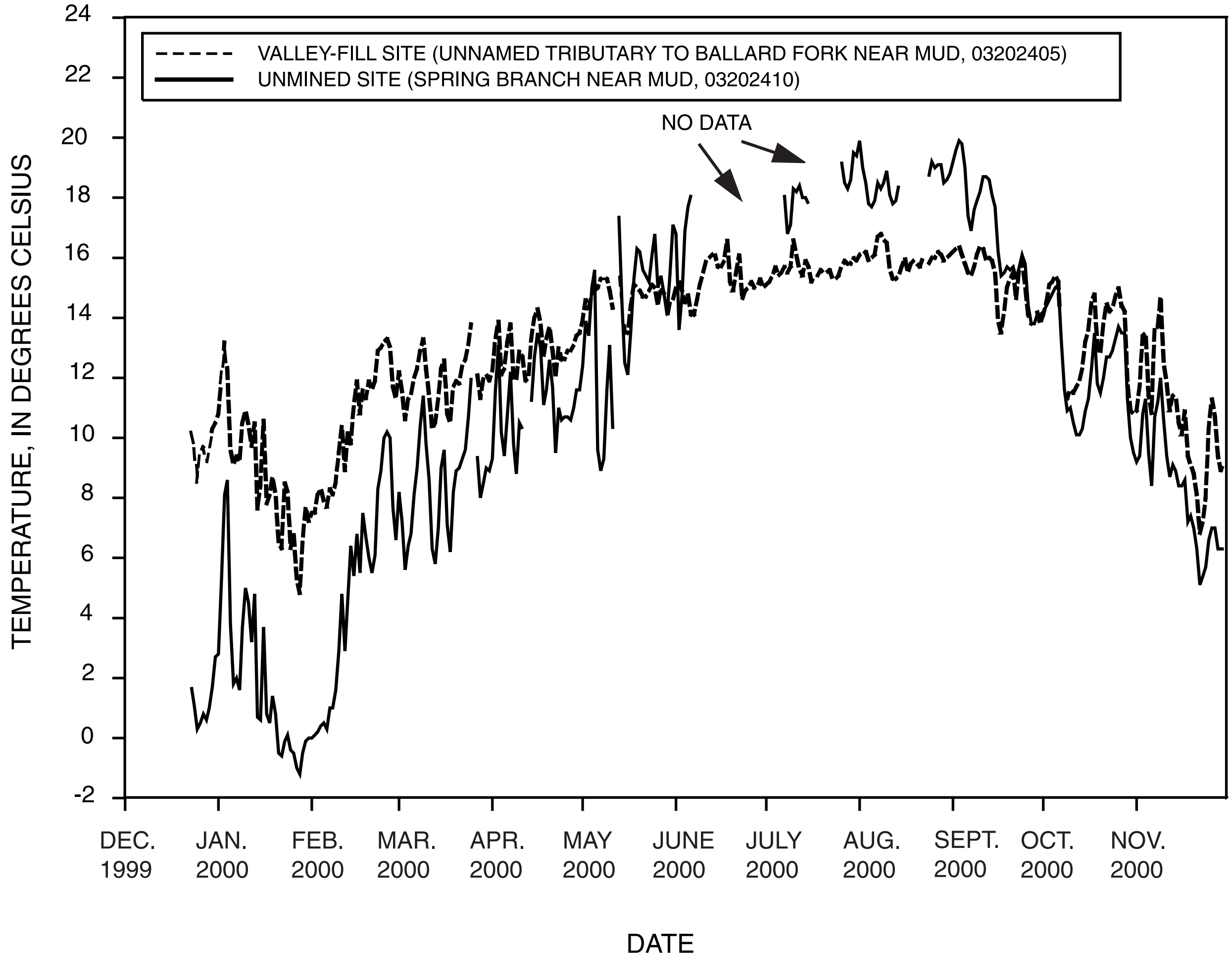

Figure 6. Daily mean water temperatures, December 1999 through November 2000, at a valley-fill and an unmined site in the coal-mining region of southern West Virginia.

SUMMARY

Mining coal by removing mountaintops and disposing of the overburden in valleys, creating valley fills, has changed the landscape in the coal-mining region of southern West Virginia and affected stream geomorphology, low streamflow, and stream temperatures. The USGS, in cooperation with the West Virginia Department of Environmental Protection, Office of Mining and Reclamation, investigated these mining effects by comparing data collected between 1999 and 2000 in four basins at valley-fill, unmined, and mined sites. Information from this study will assist in the preparation of an Environmental Impact Statement to assess the policies, guidance, and decision-making processes of regulatory agencies in order to minimize any adverse environmental effects from this mining practice.

Particle sizes were measured at 54 small stream sites in the Clear Fork, Upper Mud River, Spruce Fork, and Twentymile Creek Basins, using a modification to the procedure described by Wolman (1954). A comparison of all unmined sites indicated that distribution of particle sizes can differ among unmined basins. The different distributions among basins suggests that natural factors may have some effect over particle sizes. Valley-fill sites had a greater number of particles less than 2 millimeters in size, a smaller median particle size, and about the same 84th percentile particle size, as compared to the mined and unmined sites.

Bankfull maximum depth, width, and cross-sectional area at a riffle section were measured at the 54 small-stream sites. No differences in the bankfull measurements could be determined between valley-fill and unmined sites. Bankfull indicators at valley-fill sites may not represent the valley-fill condition if there has not been enough time and if peak streamflows since the land was disturbed have been insufficient to bring the channel to equilibrium.

Low streamflows were investigated by comparing 90-percent flow durations, daily streamflow records, base-streamflows, and stormflows. Generally, the 90-percent flow durations at valley-fill sites were 6-7 times greater than the 90-percent flow durations at unmined sites. Some valley-fill sites, however, exhibited 90-percent flow durations similar to unmined sites, and some unmined sites exhibited 90-percent flow durations similar to valley-fill sites. Daily streamflows from valley-fill sites generally are greater than daily streamflows from unmined sites during periods of low streamflow. Valley-fill sites have a greater percentage of base-streamflows and lower percentage of stormflows than unmined sites.

Stream temperature was recorded at a valley-fill site and at an unmined site. Water temperatures from a valley-fill site exhibited lower daily fluctuations and lesser seasonal variations than water temperatures from an unmined site. Water temperatures from the valley-fill site were warmer in the winter and cooler in the summer than water temperatures from the unmined site.

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TABLES

Table 4. Low streamflow, particle sizes, and channel characteristics for sampling sites in the coal-mining region of southern West Virginia

[--, no value; <, less than]

Station number	Stream name	Latitude	Longi-tude	Drain-age area, in acres	Mining class	90-per-cent flow dura-tion, in cubic feet per second	Median parti-cle size, in milli-meters	Parti-cle size of the 84th per-cen-tile, in milli-meters	Parti-cles smaller than 2 milli-meters, in per-cent	Bank-full cross-sec-tion width, in feet	Maxi-mum bankfull cross-section depth, in feet	Bank-full cross-sec-tion area, in square feet
Clear Fork Basin												
MT64	Buffalo Fork	37°53'58"	81°19'52"	758	Valley fill	0.3	<2	205	62	9.1	0.52	2.21
MT65C	Unnamed tributary to Buffalo Fork	37°53'48"	81°19'38"	65	Valley fill	.03	<2	225	57	5.8	.59	1.86
MT66	Buffalo Fork	37°53'47"	81°19'09"	373	Valley fill	.1	<2	43	56	13.5	.95	6.49
MT67 and MT68B	Unnamed tributary to Buffalo Fork Unnamed tributary to Buffalo Fork	37°53'47" 37°53'46"	81°18'55" 81°18'53"	46 221	Valley fill Valley fill	.008	2	48	70	9.9	.77	3.34
MT69	Ewing Fork	37°54'50"	81°19'30"	708	Mined	.2	10	145	41	10.5	.57	4.38
MT70	Toney Fork	37°54'38"	81°19'33"	1,221	Valley fill	.5	<2	21	72	6.0	1.04	3.53
MT71	Toney Fork	37°54'19"	81°18'07"	81	Valley fill	.04	<2	176	56	6.0	.85	3.09
MT72	Unnamed tributary to Toney Fork	37°54'17"	81°18'11"	107	Valley fill	.04	30.5	184	34	7.0	.95	4.70
MT73	Toney Fork	37°54'21"	81°18'17"	207	Valley fill	.08	--	--	--	7.0	.80	3.62
MT74	Unnamed tributary to Toney Fork	37°54'25"	81°18'40"	55	Valley fill	.001	67.5	300	29	5.0	.50	1.45
MT76	Reeds Branch	37°54'28"	81°18'46"	296	Valley fill	.06	<2	97	60	4.3	.61	1.50
MT78	Raines Fork	37°55'11"	81°24'26"	524	Mined	0	--	--	--	6.6	.73	3.04

Table 4. Low streamflow, particle sizes, and channel characteristics for sampling sites in the coal-mining region of southern West Virginia—Continued

[--, no value; <, less than]

Station number	Stream name	Latitude	Longitude	Drainage area, in acres	Mining class	90-percent flow duration, in cubic feet per second	Median particle size, in millimeters	Particle size of the 84th percentile, in millimeters	Particles smaller than 2 millimeters, in percent	Bankfull cross-section width, in feet	Maximum bankfull cross-section depth, in feet	Bankfull cross-section area, in square feet
MT79	Davis Fork	37º54'55"	81º24'10"	448	Mined	0.005	41	431	25	11.8	1.41	16.7
MT80	Lem Fork	37º54'28"	81º24'08"	689	Unmined	.01	26.5	142	38	8.4	.76	6.36
MT82	Unnamed tributary to Sycamore Creek	37º54'08"	81º24'26"	294	Mined	0	<2	72	56	8.7	.47	1.48
MT83	Unnamed tributary to Sycamore Creek	37º53'44"	81º24'11"	261	Unmined	0	98.5	197	20	5.5	.63	1.90
MT84	Sycamore Creek	37º53'42"	81º24'15"	222	Mined	0	99.5	217	26	3.8	.75	1.62
					Mud River Basin							
MT03	Lukey Fork	38º03'18"	81º57'31"	717	Unmined	.01	<2	164	53	13.0	.93	12.1
MT08	Sally Fork of Ballard Fork	38º03'47"	81º54'58"	98	Unmined	.004	<2	81	61	5.9	.58	1.94
MT09B	Sally Fork of Ballard Fork	38º03'58"	81º55'09"	39	Valley fill	.008	<2	269	59	4.6	.42	1.14
MT10B	Ballard Fork	38º04'08"	81º55'18"	152	Valley fill	.06	<2	<2	95	4.1	.51	1.43
MT11B	Left Fork of Ballard Fork	38º04'11"	81º55'20"	157	Valley fill	.07	<2	<2	86	- -	- -	- -
MT12	Unnamed tributary to Ballard Fork	38º04'10"	81º55'29"	26	Valley fill	.004	<2	<2	87	3.7	.45	1.04
MT13	Spring Branch of Ballard Fork	38º04'02"	81º56'16"	335	Unmined	.003	<2	26	69	6.4	.39	2.51

Table 4. Low streamflow, particle sizes, and channel characteristics for sampling sites in the coal-mining region of southern West Virginia—Continued

[--, no value; <, less than]

Station number	Stream name	Latitude	Longitude	Drainage area, in acres	Mining class	90-percent flow duration, in cubic feet per second	Median particle size, in millimeters	Particle size of the 84th percentile, in millimeters	Particles smaller than 2 millimeters, in percent	Bankfull cross-section width, in feet	Maximum bankfull cross-section depth, in feet	Bankfull cross-section area, in square feet
MT14	Ballard Fork	38°04’20”	81°56’49”	1,527	Valley fill	0.4	<2	42	63	12.7	0.65	8.26
MT16B	Unnamed tributary to Stanley Fork	38°04’55”	81°56’23”	516	Valley fill	.4	<2	8	83	15.3	.74	8.08
MT18	Sugartree Branch	38°05’26”	81°57’04”	479	Valley fill	.4	<2	84	52	12.4	.72	8.93
MT20B	Sugartree Branch	38°05’29”	81°56’53”	383	Valley fill	.3	<2	<2	90	6.0	1.01	4.02
					Spruce Fork Basin							
MT25B	Rockhouse Creek	37°56’01”	81°50’26”	997	Valley fill	.2	69.5	149	7	10.4	.80	4.30
MT26	Beech Creek	37°54’25”	81°52’30”	920	Mined	.002	13	260	44	2.9	.95	2.06
MT27	Unnamed tributary to Beech Creek	37°54’34”	81°52’39”	266	Mined	.001	<2	63	53	15.0	1.2	11.6
MT29B	Unnamed tributary to Beech Creek	37°54’42”	81°51’28”	81	Valley fill	.1	<2	<2	92	6.0	1.15	3.00
MT30B	Unnamed tributary to Beech Creek	37°54’35”	81°51’24”	169	Valley fill	.06	<2	16	66	3.2	.90	2.07
MT31B	Unnamed tributary to Beech Creek	37°54’39”	81°51’10”	141	Valley fill	.03	--	--	--	--	--	--
MT33B	Unnamed tributary to Beech Creek	37°54’34”	81°50’39”	69	Valley fill	.01	<2	109	61	4.5	.60	1.90
MT36B	Hurricane Branch	37°55’05”	81°50’18”	286	Valley fill	.1	<2	42	59	8.0	.85	4.60
MT37	White Oak Branch	37°51’42”	81°47’23”	320	Unmined	.007	60.5	127	6	5.9	.69	2.12

Table 4. Low streamflow, particle sizes, and channel characteristics for sampling sites in the coal-mining region of southern West Virginia—Continued

[--, no value; <, less than]

Station number	Stream name	Latitude	Longitude	Drainage area, in acres	Mining class	90-percent flow duration, in cubic feet per second	Median particle size, in millimeters	Particle size of the 84th percentile, in millimeters	Particles smaller than 2 millimeters, in percent	Bankfull cross-section width, in feet	Maximum bankfull cross-section depth, in feet	Bankfull cross-section area, in square feet
MT38	Unnamed tributary to White Oak Branch	37º51’45”	81º47’23”	84	Unmined	0	35.5	147	27	6.2	0.45	1.41
MT39	White Oak Branch	37º51’46”	81º48’14”	669	Unmined	.02	54.5	120	21	11.3	.59	3.32
MT41	Oldhouse Branch	37º52’18”	81º48’44”	226	Unmined	.04	15	71	33	8.6	.58	3.04
MT42	Oldhouse Branch	37º52’24”	81º49’20”	447	Unmined	.02	67	172	8	11.6	.89	4.78
MT43	Pigeonroost Branch	37º52’48”	81º47’46”	470	Mined	.04	<2	103	63	10.6	.88	4.58
MT44	Unnamed tributary to Pigeonroost Branch	37º52’47”	81º47’47”	294	Unmined	.003	<2	74	67	7.2	.33	1.52
Twentymile Creek Basin												
MT87	Neff Fork	38º20’41”	80º57’21”	752	Valley fill	.03	<2	135	61	12.4	.62	5.47
MT88	Unnamed tributary to Neff Fork	38º20’36”	80º57’04”	179	Mined	.07	<2	70	54	7.7	.41	1.46
MT89B	Unnamed tributary to Neff Fork	38º20’45”	80º56’34”	108	Valley fill	.04	42.5	128	34	7.1	.47	1.56
MT90	Neff Fork	38º20’41”	80º56’33”	297	Valley fill	.1	14	164	45	7.9	.52	2.66
MT91	Rader Fork	38º20’39”	80º57’30”	1,302	Unmined	.2	<2	81	79	17.8	.57	6.18
MT92	Unnamed tributary to Radar Fork	38º20’19”	80º57’28”	213	Unmined	.06	34.5	82	28	10.4	.39	2.24
MT93	Laurel Run	38º20’18”	80º57’41”	343	Unmined	.01	<2	146	57	10.1	.65	3.53

Table 4. Low streamflow, particle sizes, and channel characteristics for sampling sites in the coal-mining region of southern West Virginia—Continued

[--, no value; <, less than]

Station number	Stream name	Latitude	Longitude	Drainage area, in acres	Mining class	90-percent flow duration, in cubic feet per second	Median particle size, in millimeters	Particle size of the 84th percentile, in millimeters	Particles smaller than 2 millimeters, in percent	Bankfull cross-section width, in feet	Maximum bankfull cross-section depth, in feet	Bankfull cross-section area, in square feet
MT94	Rader Fork	38º20'16"	80º57'41"	601	Unmined	0.03	<2	23	81	12.9	0.69	5.19
MT95	Neil Branch	38º17'51"	81º05'10"	968	Unmined	.1	73.5	184	19	11.6	.59	4.50
MT96	Unnamed tributary to Neil Branch	38º18'22"	81º05'14"	58	Unmined	0	<2	110	65	11.6	.59	4.03
MT97	Neil Branch	38º18'19"	81º05'10"	654	Unmined	.2	52	141	35	6.2	.37	1.47

Table 5. Low-streamflow measurements at small-stream sampling sites in the coal-mining region of southern West Virginia

[--, no value, <, less than]

Station number	Stream name	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second
Clear Fork Basin													
MT64	Buffalo Fork	10/27/99	1420	0.249	06/08/00	1100	0.948	08/16/00	1330	0.815	10/16/00	1050	0.403
MT65C	Unnamed tributary to Buffalo Fork	10/27/99	1340	.027	06/08/00	1025	.161	08/16/00	1250	.102	10/16/00	1025	.037
MT66	Buffalo Fork	10/27/99	1225	.146	06/09/00	1128	.338	08/16/00	1115	.050	10/04/00	1610	.370
MT67 and MT68B	Unnamed tributary to Buffalo Fork Unnamed tributary to Buffalo Fork	10/27/99	1135	.008	06/09/00	1455	.446	08/17/00	1150	.338	10/16/00	0940	0.170
MT69	Ewing Fork	10/26/99	1055	.212	06/08/00	1408	.901	08/16/00	1730	.906	10/04/00	1450	7.64
MT70	Toney Fork	10/26/99	1150	.007	06/08/00	1325	.943	08/16/00	1635	.787	10/04/00	1345	.675
MT71	Toney Fork	10/26/99	1505	.042	06/08/00	1156	.063	08/06/00	1430	.046	10/04/00	1015	.088
MT72	Unnamed tributary to Toney Fork	10/26/99	- -	.046	06/08/00	1135	.290	08/16/00	1400	.126	10/04/00	1045	.105
MT73	Toney Fork	10/26/99	1540	.087	06/08/00	1215	.261	08/16/00	1505	.204	10/04/00	1130	.132
MT74	Unnamed tributary to Toney Fork	10/26/99	1335	.001	06/08/00	1235	.026	08/16/00	1525	.029	10/04/00	1210	.027
MT76	Reeds Branch	10/26/99	1240	.069	06/08/00	1250	.368	08/16/00	1550	.247	10/04/00	1250	.134
MT78	Raines Fork	- -	- -	- -	06/08/00	- -	0	08/22/00	- -	0	10/05/00	1315	0
MT79	Davis Fork	10/28/99	- -	.004	06/08/00	1000	.411	08/22/00	1210	.181	10/24/00	1105	.065
MT80	Lem Fork	10/28/99	- -	.012	06/08/00	1030	.359	08/22/00	1045	.092	10/27/00	1350	.018

Table 5. Low-streamflow measurements at small-stream sampling sites in the coal-mining region of southern West Virginia—Continued

[--, no value, <, less than]

Station number	Stream name	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second
MT82	Unnamed tributary to Sycamore Creek	10/28/99	--	0	06/08/00	--	0	08/22/00	--	0	10/05/00	1245	0
MT83	Unnamed tributary to Sycamore Creek	10/28/99	--	0	--	--	--	--	--	--	10/05/00	1111	.035
MT84	Sycamore Creek	10/28/99	--	0	--	--	--	--	--	--	10/05/00	1130	0
Mud River Basin													
MT03	Lukey Fork	10/26/99	--	.014	06/06/00	1350	.194	08/17/00	1550	.103	08/31/00	1045	.015
MT08	Sally Fork of Ballard Fork	10/25/99	--	.004	06/06/00	--	.006	08/17/00	1353	.009	09/06/00	1220	.016
MT09B	Sally Fork of Ballard Fork	10/25/99	1610	.008	06/06/00	1230	.016	08/17/00	1442	.099	09/06/00	1145	.008
MT10B	Ballard Fork	10/25/99	1500	.059	06/06/00	1130	.186	08/17/00	1131	.323	09/06/00	1112	.195
MT11B	Left Fork of Ballard Fork	10/25/99	1438	.075	06/08/00	1115	.093	08/17/00	--	.109	--	--	--
MT12	Unnamed tributary to Ballard Fork	10/25/99	1336	.004	06/08/00	1100	.007	08/17/00	1155	.024	09/06/00	1015	.008
MT13	Spring Branch of Ballard Fork	10/25/99	1125	.004	06/06/00	1030	.110	08/17/00	--	.073	10/12/00	1205	.007
MT14	Ballard Fork	10/25/99	1000	.375	06/06/00	0930	.781	08/17/00	1000	.082	9/13/00	1405	.435
MT16B	Unnamed tributary to Stanley Fork	10/25/99	--	.414	06/06/00	1500	.719	08/17/00	1834	1.26	09/06/00	1415	1.23
MT18	Sugartree Branch	10/25/99	--	.376	06/06/00	1600	.672	08/17/00	1652	1.62	9/28/00	1237	.622
MT20B	Sugartree Branch	10/25/99	--	.266	06/06/00	1535	.612	08/17/00	1709	1.28	10/05/00	1642	.541

Table 5. Low-streamflow measurements at small-stream sampling sites in the coal-mining region of southern West Virginia—Continued

[--, no value, <, less than]

Station number	Stream name	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second
Spruce Fork Basin													
MT25B	Rockhouse Creek	11/01/99	1545	0.089	06/07/00	1555	1.10	08/17/00	1730	1.81	10/13/00	1400	0.641
MT26	Beech Creek	11/09/99	1050	.413	06/07/00	1140	.055	08/17/00	1030	4.97	10/03/00	1130	.010
MT27	Unnamed tributary to Beech Creek	11/09/99	- -	<.001	06/07/00	1105	1.63	08/17/00	1115	.277	10/03/00	1055	1.46
MT29B	Unnamed tributary to Beech Creek	11/09/99	1100	.109	06/07/00	0945	.333	08/17/00	1425	.611	10/03/00	1315	.165
MT30B	Unnamed tributary to Beech Creek	11/09/99	1138	.069	06/07/00	1220	.245	08/17/00	1450	.492	10/03/00	1240	.163
MT31B	Unnamed tributary to Beech Creek	11/09/99	- -	.042	06/07/00	- -	.188	08/17/00	1515	.372	10/03/00	1230	.191
MT33B	Unnamed tributary to Beech Creek	11/09/99	- -	.015	06/07/00	1355	.046	08/17/00	1600	.039	10/03/00	1415	.015
MT36B	Hurricane Branch	11/09/99	1340	.172	06/07/00	1455	.320	08/17/00	1645	.658	10/03/00	1500	.315
MT37	White Oak Branch	11/01/99	1240	.005	06/07/00	1225	.023	08/21/00	1610	.050	10/03/00	1451	.023
MT38	Unnamed tributary to White Oak Branch	11/01/99	1300	0	06/07/00	1240	.035	08/21/00	1600	.057	10/13/00	1015	.026
MT39	White Oak Branch	11/01/99	1405	.014	06/07/00	1315	.057	08/21/00	1510	.246	10/13/00	1100	.063
MT41	Oldhouse Branch	11/01/99	1005	.024	06/07/00	1050	.216	08/21/00	1250	.195	10/03/00	1203	.157
MT42	Oldhouse Branch	11/01/99	1100	.010	06/07/00	1110	.190	08/21/00	1330	.245	10/03/00	1110	.138
MT43	Pigeonroost Branch	11/09/99	1330	.081	06/07/00	0950	.426	08/17/00	1245	.778	10/13/00	1150	.203

Table 5. Low-streamflow measurements at small-stream sampling sites in the coal-mining region of southern West Virginia—Continued

[--, no value, <, less than]

Station number	Stream name	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second
MT44	Unnamed tributary to Pigeonroost Branch	11/09/99	1335	0.003	06/07/00	1000	0.090	08/17/00	1315	0.402	10/13/00	1210	0.047
Twentymile Creek Basin													
MT87	Neff Fork	11/10/99	1345	.402	06/06/00	1912	3.33	08/21/00	1253	.704	11/09/00	1155	.448
MT88	Unnamed tributary to Neff Fork	11/10/99	1340	.089	06/06/00	1903	.30	08/16/00	- -	.193	11/09/00	1130	.064
MT89B	Unnamed tributary to Neff Fork	11/10/99	1450	.056	06/06/00	1816	.420	08/16/00	1357	.232	10/04/00	1527	.135
MT90	Neff Fork	11/10/99	1455	.201	06/06/00	1829	1.60	08/16/00	1428	.478	11/09/00	1055	.286
MT91	Rader Fork	11/10/99	1235	.358	06/06/00	1941	4.84	08/21/00	1237	.667	11/09/00	1235	.267
MT92	Unnamed tributary to Radar Fork	11/10/99	1230	.089	06/06/00	1634	.510	08/21/00	1402	.061	10/04/00	1620	.050
MT93	Laurel Run	11/10/99	1125	.018	06/06/00	1605	1.26	08/21/00	1524	.285	10/04/00	1728	.213
MT94	Rader Fork	11/10/99	1135	.077	06/06/00	1542	2.07	08/21/00	1449	.302	10/04/00	1700	.390
MT95	Neil Branch	10/29/99	1150	.002	06/06/00	1016	.670	08/16/00	1155	.735	10/04/00	1238	.353
MT96	Unnamed tributary to Neil Branch	10/29/99	1315	.0002	06/06/00	1122	.044	08/16/00	1105	.196	10/04/00	1139	.351
MT97	Neil Branch	10/29/99	1355	.180	06/06/00	1131	.510	08/16/00	1130	.803	10/04/00	1046	.031

Table 6. Maximum, minimum, and mean water temperature in degrees Celsius, December 1999 through November 2000, at Unnamed Tributary to Ballard Fork near Mud (03202405) in the coal-mining region of southern West Virginia

[--, no value]

Day	December			January			February			March		
	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean
1	--	--	--	12.5	9.0	10.8	8.2	6.6	7.5	13.7	10.9	12.2
2	--	--	--	13.3	10.9	12.0	9.0	6.6	7.5	13.3	10.2	11.5
3	--	--	--	14.1	12.5	13.2	9.8	6.6	8.1	12.1	9.4	10.6
4	--	--	--	13.3	9.8	12.2	9.4	7.8	8.3	13.3	10.2	11.3
5	--	--	--	10.2	7.0	9.6	9.0	6.6	7.9	14.4	9.8	11.4
6	--	--	--	10.6	8.2	9.1	9.4	6.6	7.7	15.2	10.2	12.0
7	--	--	--	10.6	8.6	9.4	10.6	7.0	8.3	15.6	10.2	12.3
8	--	--	--	10.9	7.4	9.2	12.5	6.6	8.1	15.9	10.9	12.9
9	--	--	--	11.7	9.4	10.5	10.9	7.0	8.5	15.6	12.0	13.3
10	--	--	--	12.1	9.8	10.9	11.7	7.8	9.5	14.4	10.6	12.3
11	--	--	--	10.9	9.0	10.4	10.9	9.4	10.4	12.1	10.2	11.4
12	--	--	--	11.3	8.2	9.7	9.4	7.8	8.9	11.7	9.7	10.3
13	--	--	--	11.7	8.6	10.5	11.7	8.2	10.2	12.5	9.0	10.5
14	--	--	--	8.6	7.0	7.6	11.0	7.8	9.8	14.1	9.8	11.3
15	--	--	--	10.2	6.6	8.4	12.1	10.6	11.1	15.2	10.2	12.3
16	--	--	--	11.7	8.6	10.6	13.3	10.6	11.9	13.3	12.1	12.6
17	--	--	--	8.6	7.0	7.8	11.7	9.8	10.8	12.1	9.4	10.8
18	--	--	--	8.6	7.4	8.1	12.9	9.4	11.6	12.9	8.6	10.5
19	--	--	--	9.8	8.2	8.7	12.1	9.4	11.3	13.3	10.6	11.7
20	--	--	--	8.6	7.0	8.1	12.1	11.7	11.9	12.9	11.3	11.9
21	--	--	--	7.4	5.3	6.5	12.9	10.9	11.6	12.5	10.9	11.8
22	--	--	--	7.4	4.9	6.3	12.9	10.9	11.9	14.8	10.9	12.4
23	10.9	9.4	10.2	9.4	7.4	8.5	14.1	12.1	12.9	15.9	10.6	12.6
24	10.2	9.0	9.8	8.6	7.0	8.2	14.1	12.1	13.0	16.7	10.9	13.1
25	9.4	7.8	8.5	7.4	5.3	6.3	15.2	12.1	13.2	16.3	12.5	13.8
26	10.2	8.2	9.5	7.8	6.2	6.8	15.2	12.1	13.3	--	--	--
27	10.2	9.4	9.7	6.6	4.1	5.3	13.7	12.1	13.0	14.1	10.9	12.1
28	9.4	9.0	9.2	7.0	3.3	4.8	13.7	10.6	11.7	12.9	10.6	11.3
29	10.6	9.4	9.7	8.6	4.9	6.5	14.1	9.8	11.3	15.2	10.2	12.0
30	11.7	9.4	10.3	8.2	7.0	7.7	--	--	--	15.6	10.2	12.1
31	11.7	9.4	10.5	8.2	6.6	7.2	--	--	--	15.6	9.4	11.9
Month	--	--	--	14.1	3.3	8.7	15.2	6.6	10.4	--	--	--

Table 6. Maximum, minimum, and mean water temperature in degrees Celsius, December 1999 through November 2000, at Unnamed Tributary to Ballard Fork near Mud (03202405) in the coal-mining region of southern West Virginia—Continued

[--, no value]

Day	April			May			June			July		
	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean
1	15.9	9.4	12.2	17.4	11.7	13.9	16.7	14.1	15.0	16.7	14.1	15.1
2	14.1	12.5	13.3	17.4	12.5	14.6	17.4	14.1	15.2	17.1	14.1	15.2
3	15.6	12.9	13.9	17.8	11.7	14.3	16.3	14.4	14.9	17.1	14.4	15.4
4	13.3	11.3	12.1	17.1	13.7	14.8	16.7	12.9	14.5	16.3	15.2	15.7
5	14.8	10.9	12.3	17.1	13.3	14.9	17.1	13.7	14.8	15.9	15.2	15.4
6	15.6	11.7	13.2	17.1	13.3	15.0	15.2	13.7	14.1	17.1	15.2	15.5
7	16.7	12.1	13.8	18.6	13.7	15.3	17.1	12.1	14.1	17.4	14.8	15.7
8	13.3	10.8	12.0	18.2	14.1	15.3	17.4	12.5	14.6	17.8	14.1	15.5
9	14.1	10.6	11.9	17.8	14.1	15.3	18.2	13.3	15.1	17.8	14.4	15.7
10	15.6	10.9	12.9	17.1	12.9	14.9	18.2	14.1	15.5	19.8	15.2	16.6
11	13.3	12.1	12.7	17.4	12.1	14.3	18.6	14.4	15.9	18.6	15.2	16.1
12	12.9	10.6	11.9	--	--	--	17.8	14.8	16.0	16.7	15.2	15.6
13	16.3	10.2	12.0	17.4	14.4	15.4	18.6	14.8	16.1	16.3	14.8	15.4
14	17.1	10.9	13.3	17.1	12.5	14.2	18.2	14.8	16.1	18.6	14.8	15.9
15	15.9	12.5	14.0	16.3	11.7	13.5	17.1	14.8	15.7	16.7	14.8	15.7
16	16.3	13.3	14.3	16.7	11.3	13.5	17.8	14.8	15.7	16.3	14.8	15.2
17	15.6	12.9	13.8	17.1	13.3	14.4	17.5	15.2	15.9	16.7	14.8	15.4
18	12.9	12.5	12.7	17.8	13.7	15.1	19.4	15.2	16.6	16.3	14.8	15.4
19	15.6	12.1	13.3	15.9	14.4	15.0	16.1	14.8	15.2	17.1	15.2	15.6
20	15.9	11.7	13.7	15.6	14.4	14.9	15.9	14.4	14.9	16.7	14.8	15.5
21	14.1	11.7	12.9	15.9	14.1	14.7	18.0	14.4	15.5	17.1	14.4	15.5
22	12.5	11.7	12.0	16.3	13.7	14.7	20.5	14.6	16.1	17.1	14.8	15.6
23	16.3	10.9	13.0	17.1	14.1	14.9	15.6	14.1	14.6	16.7	14.4	15.3
24	13.3	11.7	12.6	16.7	14.1	15.1	16.3	14.4	14.9	15.9	14.8	15.3
25	13.7	12.1	12.6	16.7	14.4	15.0	16.3	14.4	15.0	16.7	14.4	15.4
26	15.6	11.3	12.9	16.7	12.5	14.4	16.7	14.4	15.2	17.1	14.8	15.7
27	15.9	10.9	12.9	18.2	14.1	15.0	15.4	14.8	15.0	17.8	14.8	15.9
28	15.6	11.3	13.1	17.6	14.1	14.8	15.6	14.8	15.0	17.4	15.2	15.8
29	15.6	12.1	13.4	14.4	13.7	14.0	16.7	14.8	15.3	16.7	15.2	15.8
30	17.1	11.3	13.5	16.3	13.3	14.5	16.7	14.1	15.0	17.1	15.2	16.0
31	--	--	--	16.7	13.3	14.6	--	--	--	17.1	15.6	15.9
Month	17.1	9.4	12.9	--	--	--	20.5	12.1	15.2	19.8	14.1	15.6

Table 6. Maximum, minimum, and mean water temperature in degrees Celsius, December 1999 through November 2000, at Unnamed Tributary to Ballard Fork near Mud (03202405) in the coal-mining region of southern West Virginia—Continued

[--, no value]

Day	August			September			October			November		
	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean
1	17.4	15.6	16.1	17.4	15.6	16.2	15.6	12.9	14.1	13.3	9.4	10.9
2	17.4	15.2	16.1	17.4	15.6	16.3	18.6	13.3	14.5	14.1	10.2	11.7
3	17.4	15.6	16.2	17.1	15.9	16.4	17.1	14.4	15.1	14.8	12.5	13.4
4	16.7	15.6	15.9	17.1	15.6	16.1	16.7	14.4	15.2	14.1	12.5	13.5
5	17.4	15.2	16.0	16.1	15.6	15.8	17.1	14.4	15.4	12.5	10.2	11.4
6	17.1	15.2	16.1	17.1	14.4	15.5	15.6	14.8	15.2	13.3	9.0	10.8
7	18.6	15.6	16.7	17.4	14.4	15.4	14.8	12.5	13.1	14.8	12.9	13.7
8	19.0	15.6	16.8	16.7	15.2	15.7	12.9	10.2	11.6	15.2	12.5	13.7
9	18.2	15.6	16.6	17.4	15.2	16.1	12.1	10.2	11.3	15.2	14.1	14.7
10	18.2	15.6	16.5	19.4	15.6	16.4	13.7	10.6	11.6	14.1	11.7	12.5
11	16.3	15.2	15.6	17.1	15.9	16.3	14.1	10.2	11.5	12.5	11.3	11.8
12	16.3	14.8	15.3	16.7	15.6	15.9	14.4	10.2	11.7	12.5	9.4	10.9
13	16.7	14.4	15.3	17.1	15.6	16.0	14.4	10.2	11.9	12.9	10.2	11.4
14	17.1	14.4	15.4	17.1	15.2	15.9	14.8	10.9	12.3	12.5	10.6	11.4
15	17.1	14.8	15.7	16.1	14.4	15.5	15.2	12.1	13.2	11.3	9.8	10.5
16	17.4	15.2	16.0	14.9	12.9	13.9	15.6	12.1	13.6	11.3	9.0	10.1
17	16.3	14.8	15.5	15.6	12.1	13.5	15.6	14.1	14.5	11.7	9.8	10.9
18	16.3	15.6	15.8	15.6	12.9	14.2	15.6	14.1	14.8	9.8	9.0	9.4
19	17.1	15.2	15.9	16.7	14.1	15.0	14.8	11.7	13.0	9.8	8.6	9.1
20	17.1	14.8	15.8	17.1	14.4	15.3	15.2	11.3	12.8	9.8	7.8	8.8
21	17.1	14.8	15.7	16.7	14.8	15.5	15.2	12.9	13.8	8.6	7.4	8.1
22	17.4	15.2	16.0	16.3	13.3	14.6	15.9	13.7	14.5	8.6	5.8	6.8
23	--	--	--	17.1	14.8	15.6	15.9	12.9	14.2	9.4	5.8	7.2
24	16.3	15.2	15.8	16.3	15.6	15.9	15.6	13.3	14.3	10.6	6.6	8.0
25	17.1	15.6	16.0	15.9	14.8	15.1	15.6	13.7	14.7	11.7	9.0	10.3
26	17.1	15.2	16.0	14.8	13.7	14.1	16.3	14.4	15.0	11.7	10.9	11.3
27	17.4	15.6	16.2	15.6	12.5	13.8	15.9	13.3	14.4	11.3	9.4	10.7
28	17.1	15.6	16.1	15.6	12.5	13.8	14.8	13.3	14.2	10.9	8.6	9.4
29	17.4	15.2	15.9	15.9	12.9	14.2	13.7	10.2	11.8	10.9	7.4	8.9
30	17.4	14.8	16.0	15.9	12.9	14.1	12.9	9.4	10.9	9.8	9.0	9.2
31	17.4	15.2	16.1	--	--	--	13.3	9.4	10.8	--	--	--
Month	--	--	--	19.4	12.1	15.3	18.6	9.4	13.4	15.2	5.8	10.7

Table 7. Maximum, minimum, and mean water temperature in degrees Celsius, December 1999 through November 2000, at Spring Branch near Mud (03202410) in the coal-mining region of southern West Virginia

[- - , no value]

Day	December			January			February			March		
	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean
1	--	--	--	4.5	1.1	2.8	.2	-.1	.0	10.9	5.3	8.2
2	--	--	--	7.0	3.7	5.3	.7	-.1	.1	9.4	5.1	7.2
3	--	--	--	9.4	6.6	8.1	.7	-.1	.2	7.8	3.3	5.6
4	--	--	--	10.2	4.9	8.6	1.1	.2	.4	9.8	4.5	6.4
5	--	--	--	4.9	2.0	3.8	1.6	-.1	.5	10.9	3.7	6.8
6	--	--	--	3.3	.7	1.8	1.1	-.1	.3	12.5	4.9	8.1
7	--	--	--	3.7	1.1	2.0	2.8	-.1	1.0	13.7	5.3	9.0
8	--	--	--	2.8	.2	1.6	3.3	-.1	1.0	15.2	7.0	10.4
9	--	--	--	5.3	2.4	3.7	4.5	-.1	1.6	14.8	9.4	11.4
10	--	--	--	7.0	3.7	5.0	5.3	.7	2.9	12.5	7.4	9.8
11	--	--	--	6.2	3.1	4.5	5.3	3.7	4.8	9.4	7.8	8.6
12	--	--	--	4.5	1.6	3.2	3.7	2.0	2.9	7.8	4.9	6.3
13	--	--	--	6.2	2.2	4.8	6.8	2.4	4.6	8.2	3.7	5.8
14	--	--	--	2.2	.2	.7	7.0	5.3	6.4	10.2	4.5	7.0
15	--	--	--	1.8	-.1	.6	6.6	4.9	5.4	12.9	6.2	9.0
16	--	--	--	5.3	1.8	3.7	9.0	5.3	6.8	10.6	9.0	9.6
17	--	--	--	2.6	.2	.8	7.0	4.1	5.5	9.4	4.9	7.1
18	--	--	--	.7	.2	.5	9.0	5.8	7.5	8.6	3.7	6.2
19	--	--	--	2.4	.7	1.4	8.2	5.8	6.7	10.6	6.6	8.2
20	--	--	--	1.1	-.1	.8	6.6	5.8	6.0	10.2	8.2	8.9
21	--	--	--	-.1	-1.0	-.5	5.8	5.3	5.5	9.8	8.2	9.0
22	--	--	--	-.1	-1.4	-.6	7.8	4.9	6.1	12.5	7.4	9.3
23	2.8	.7	1.7	-.1	-.1	-.1	10.6	6.6	8.3	14.1	6.6	9.6
24	2.0	.2	1.1	.2	-.1	.1	10.9	7.0	8.9	15.2	7.4	10.7
25	.7	.2	.3	-.1	-.6	-.4	13.3	7.8	10.0	15.2	9.8	12.0
26	1.1	.2	.5	-.1	-.6	-.5	13.7	7.8	10.2	--	--	--
27	1.1	.2	.8	-.6	-1.9	-1.0	10.6	8.8	10.0	11.7	7.8	9.4
28	.7	.2	.6	-.1	-2.4	-1.2	10.6	5.5	7.7	10.2	7.0	8.0
29	2.0	.7	1.0	-.1	-1.0	-.5	10.6	3.7	6.6	12.5	6.2	8.5
30	3.3	.2	1.7	.2	-.1	-.1	--	--	--	13.7	6.2	9.0
31	4.5	1.8	2.7	.2	-.1	.0	--	--	--	14.1	5.3	8.9
Month	--	--	--	10.2	-2.4	1.9	13.7	-.1	4.8	--	--	--

Table 7. Maximum, minimum, and mean water temperature in degrees Celsius, December 1999 through November 2000, at Spring Branch near Mud (03202410) in the coal-mining region of southern West Virginia—Continued

[- - , no value]

Day	April			May			June			July		
	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean
1	4.8	4.9	9.3	16.3	9.0	12.4	18.9	15.5	16.8	--	--	--
2	12.9	10.6	11.6	17.1	12.5	13.9	15.5	11.6	13.6	--	--	--
3	15.6	11.3	13.1	17.4	10.2	13.4	18.6	10.9	14.8	--	--	--
4	12.1	8.2	10.2	17.4	13.7	15.0	19.8	14.8	16.9	--	--	--
5	12.5	7.4	9.4	18.2	13.7	15.6	20.9	15.9	17.7	--	--	--
6	14.4	8.6	10.8	15.6	6.2	9.6	20.9	17.1	18.1	--	--	--
7	16.3	9.4	12.2	14.1	5.3	8.9	--	--	--	19.0	17.4	18.1
8	11.3	7.8	9.8	14.8	4.9	9.3	--	--	--	17.8	15.6	16.8
9	12.1	6.6	8.8	12.9	10.6	11.6	--	--	--	18.2	15.9	17.1
10	14.4	7.8	10.5	15.6	11.3	13.1	--	--	--	20.2	17.4	18.3
11	11.3	9.4	10.3	12.1	8.6	10.3	--	--	--	18.6	17.8	18.2
12	--	--	--	--	--	--	--	--	--	19.4	17.4	18.4
13	--	--	--	19.0	16.7	17.4	--	--	--	18.6	17.1	18.0
14	16.7	7.4	11.2	17.3	12.5	14.5	--	--	--	18.6	17.1	18.0
15	15.9	10.6	12.7	15.2	10.2	12.5	--	--	--	18.6	16.3	17.8
16	15.9	11.7	13.5	14.8	9.8	12.1	--	--	--	--	--	--
17	15.6	11.7	13.0	15.9	12.5	13.6	--	--	--	--	--	--
18	12.1	10.6	11.1	18.2	14.1	15.3	--	--	--	--	--	--
19	14.4	10.6	11.6	17.4	15.6	16.3	--	--	--	--	--	--
20	15.9	9.4	12.6	17.0	15.9	16.2	--	--	--	--	--	--
21	13.7	9.8	11.7	16.7	14.8	15.6	--	--	--	--	--	--
22	9.8	9.0	9.5	16.3	14.8	15.4	--	--	--	--	--	--
23	15.2	7.8	11.0	16.3	14.4	15.2	--	--	--	--	--	--
24	11.3	9.4	10.6	18.2	14.8	16.1	--	--	--	--	--	--
25	11.7	10.2	10.7	17.7	16.3	16.8	--	--	--	--	--	--
26	13.7	8.6	10.7	17.0	12.9	15.0	--	--	--	19.8	18.6	19.2
27	14.1	7.8	10.6	16.7	14.8	15.4	--	--	--	19.0	18.2	18.5
28	13.7	8.6	11.0	15.7	14.4	14.8	--	--	--	19.0	17.8	18.3
29	14.1	9.8	11.6	14.8	13.7	14.1	--	--	--	19.0	18.2	18.6
30	15.6	8.6	11.6	18.2	13.7	15.4	--	--	--	20.5	18.6	19.5
31	--	--	--	19.4	15.6	17.1	--	--	--	20.2	19.0	19.4
Month	--	--	--	--	--	--	--	--	--	--	--	--

Table 7. Maximum, minimum, and mean water temperature in degrees Celsius, December 1999 through November 2000, at Spring Branch near Mud (03202410) in the coal-mining region of southern West Virginia—Continued

[- - , no value]

Day	August			September			October			November		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean
1	20.9	19.0	19.9	20.9	18.6	19.2	14.4	14.1	14.2	10.2	8.2	9.2
2	19.8	18.2	19.0	20.5	19.0	19.6	15.9	14.1	14.4	10.9	8.2	9.4
3	19.4	17.4	18.5	20.5	19.4	19.9	15.6	14.1	14.6	11.7	10.2	10.8
4	18.6	16.7	17.8	20.9	19.4	19.8	15.6	14.1	14.8	11.7	10.9	11.3
5	18.6	17.1	17.7	20.3	18.2	19.0	15.6	14.4	15.0	11.0	8.6	9.5
6	18.6	17.1	17.9	18.6	16.3	17.4	15.3	14.8	15.1	10.2	7.0	8.4
7	19.0	17.4	18.5	18.6	15.9	16.9	14.8	12.5	13.2	11.3	10.2	10.7
8	19.4	17.1	18.3	18.2	17.1	17.6	12.6	10.6	11.6	12.1	10.6	11.2
9	19.0	17.4	18.5	18.2	17.4	17.9	11.4	10.2	10.9	12.8	11.7	12.0
10	19.8	18.2	18.9	20.2	17.8	18.2	11.7	10.6	11.0	12.9	9.0	10.6
11	19.4	17.1	18.1	19.1	18.2	18.7	11.7	9.4	10.5	10.2	9.0	9.4
12	19.0	16.3	17.8	19.0	18.6	18.7	11.7	9.0	10.1	10.2	7.4	8.7
13	19.0	16.7	17.9	19.0	18.2	18.6	11.3	9.0	10.1	10.6	8.2	9.1
14	19.8	17.4	18.4	18.6	17.8	18.1	11.7	9.4	10.3	9.8	8.2	8.9
15	--	--	--	18.6	17.1	17.7	11.7	10.2	10.9	9.0	8.2	8.4
16	--	--	--	17.1	15.6	16.2	12.1	10.6	11.3	9.4	7.8	8.4
17	--	--	--	15.9	14.8	15.4	12.9	12.1	12.3	9.4	7.4	8.6
18	--	--	--	15.9	15.2	15.5	14.4	12.5	13.5	7.4	7.0	7.2
19	--	--	--	15.9	15.6	15.7	13.0	10.9	11.8	7.8	7.0	7.4
20	--	--	--	15.9	15.2	15.6	12.5	10.6	11.5	7.4	6.6	7.0
21	--	--	--	15.9	15.6	15.7	12.9	11.3	12.0	6.7	5.8	6.3
22	--	--	--	15.6	14.8	15.3	13.3	12.5	12.7	5.8	4.5	5.1
23	--	--	--	15.9	15.6	15.7	13.3	12.1	12.7	6.2	4.5	5.4
24	19.4	18.2	18.7	16.3	15.9	16.1	13.3	12.5	12.9	7.0	4.9	5.7
25	20.5	18.6	19.2	16.3	14.8	15.8	13.7	12.9	13.3	7.4	6.2	6.6
26	19.9	18.2	19.0	15.2	14.1	14.4	14.1	13.3	13.7	7.0	7.0	7.0
27	20.5	18.2	19.1	14.4	13.3	13.8	14.1	12.9	13.5	7.4	6.2	7.0
28	19.9	18.6	19.1	14.4	13.3	13.8	14.1	12.9	13.5	7.4	5.3	6.3
29	20.2	17.4	18.5	14.8	13.7	14.1	13.4	10.6	11.3	7.4	5.3	6.3
30	19.8	17.4	18.6	14.4	13.7	14.1	10.9	9.0	10.0	6.7	5.8	6.3
31	19.4	18.2	18.8	--	--	--	10.6	8.6	9.5	--	--	--
Month	--	--	--	20.9	13.3	16.8	15.9	8.6	12.3	12.9	4.5	8.3

U.S. Fish & Wildlife Service

The Value of Headwater Streams: Results of a Workshop, State College, Pennsylvania, April 13, 1999

April 2000

Sponsored by:

Pennsylvania Field Office,
Suite 322, 315 South Allen Street,
State College, Pennsylvania

THE VALUE OF HEADWATER STREAMS

Results of a Workshop
State College, Pennsylvania
April 13, 1999

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U.S. Fish and Wildlife Service
Pennsylvania Field Office
State College, Pennsylvania

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Arch Coal, Inc., Huntington, West Virginia

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University of Georgia, Athens, Georgia

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Stroud Water Research Center, Avondale, Pennsylvania

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FOREWORD

The U.S. Environmental Protection Agency, U.S. Office of Surface Mining, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and West Virginia Division of Environmental Protection are cooperating in the preparation of an Environmental Impact Statement (EIS) on mountaintop mining operations and valley fills in the Appalachian coal fields. As announced in the *Federal Register*, the purpose of the EIS is to:

> ...consider developing agency policies, guidance, and coordinated agency decision-making processes to minimize, to the extent practicable, the adverse environmental effects to waters of the United States and to fish and wildlife resources from mountaintop mining operations, and to environmental resources that could be affected by the size and location of fill material in valley fill sites.

As a result of the public EIS scoping process, the potential for valley filling to adversely affect streams emerged as a priority issue. The multi-agency EIS steering committee identified the following questions, among others, that need to be addressed during preparation of the EIS:

- How will we measure the effects (impacts) of mountaintop mining operations and associated valley fills on streams and aquatic life?

- What are the short- and long-term effects of individual mountaintop mining operations and associated valley fills on the physical, chemical, and biological conditions of affected streams and their watersheds, both within the area of direct impact and downstream? In answering this, consider water quality and quantity, changes in aquatic habitat, and stream use.

- What are the expected effects likely to be on aquatic species of federal and state concern (i.e., listed and proposed threatened and endangered species, candidate species, and species of special concern)?

- What are the relative individual and cumulative effects of a single large valley fill versus multiple small headwater fills? In answering this question, assess the relative value of headwaters and their contribution to the physical, chemical, and biological health of the larger watershed.

- How do we reach a better scientific consensus on the water quality/aquatic habitat values of valley headwater streams so that the on-site impacts of fills, and the resulting mitigation, restoration, and reclamation requirements can be judged more effectively -- both in the fill area and downstream? What does "minimize" environmental damages mean in this context?

- What criteria should be used to determine whether a fill may be placed in a stream?

- What is a stream? The agencies should develop a mutually acceptable approach for reconciling the interagency and interstate differences concerning the definition of streams.

To gather information relative to these questions, a one-day invitational meeting was organized by the Pennsylvania Field Office of the U.S. Fish and Wildlife Service to discuss the value of headwater streams. Experts from industry, government, and academia attended. In advance of the meeting, participants were sent the following list of questions, to be discussed at the meeting:

- What is a stream?

    - At what point in the upper reaches of a stream do regulators stop regulating?

    - How far upstream should we regulate to ensure that downstream functions and quality are maintained?

- Are stream classifications such as perennial, intermittent, or ephemeral ecologically useful or even relevant in this context?

- What indicators do we use to define these conditions? Flows? Fish presence? Invertebrate abundance and/or diversity?

• What can we afford to lose?

  - In evaluating the cumulative impacts of more than one valley fill, what size watershed do we evaluate?

  - How many streams can be eliminated by valley filling in a given watershed before the downstream aquatic ecosystem is unacceptably impaired?

  - If we assume that the amount of overburden material that needs to be disposed of is a constant, is one valley fill or a few very large valley fills better for the environment than more numerous small valley fills at the upper reaches of more valleys?

The meeting was held on April 13, 1999, in State College, Pennsylvania. Participants were informed that the meeting was being tape-recorded, and that the transcript would become part of the formal EIS record.

This report constitutes the meeting record, compiled from notes recorded during the meeting by EPA's Rebecca Hanmer, text slides or overheads used by presenters, and transcription of the meeting tapes by FWS's Cindy Tibbott. In addition, each presenter was given the opportunity to edit a draft transcript of his presentation. The meeting was informal and interactive, so discussions of various technical and regulatory issues are interspersed throughout the speakers' presentations and are delineated by use of a "SMALL CAP" font. Due to space limitations, many of the presenters' slides are not included here.

The State College meeting agenda also included a discussion of technical issues related to the EIS work plan for studying the effects of valley fills on streams. Because that discussion occurred early in the development of the study, and resulted in numerous follow-up discussions and iterations of the work plan, it is not included here.

The EIS steering committee extends its sincere appreciation to the speakers and participants for taking the time to share their expertise and insights on this important issue.

List of Participants

John Arway, Pennsylvania Fish and Boat Commission, Bellefonte, PA
Frank Borsuk, Potesta and Associates, Inc., Charleston, WV
Robert Brooks, The Pennsylvania State University, University Park, PA
Hope Childers, EPA, Wheeling, WV
David Densmore, U.S. FWS, State College, PA
Larry Emerson, Arch Coal, Huntington, WV
Diana Esher, EPA, Philadelphia, PA
Jim Green, EPA, Wheeling, WV
Steven N. Handel, Rutgers University, Bridgewater, NJ
Rebecca Hanmer, EPA, Washington, D.C.
Dave Hartos, OSM, Pittsburgh, PA
William Hoffman, EPA, Philadelphia, PA
Steve Kepler, Pennsylvania Fish and Boat Commission, Bellefonte, PA
George Kincaid, U.S. Army Corps of Engineers, Apple Grove, WV
Fred Kirschner, U.S. Army Corps of Engineers, Apple Grove, WV
Jerry Legg, Virginia DMME, Big Stone Gap, VA
Bernie Maynard, OSM, Pittsburgh, PA
Dan McGarvey, The Pennsylvania State University, University Park, PA
Dennis Newbold, Stroud Water Research Center, Avondale, PA
Maggie Passmore, EPA, Wheeling, WV
Ken Politan, WV DEP, Nitro, WV
Randy Pomponio, Canaan Valley Institute, Valley Forge, PA
Dan Ramsey, FWS, Elkins, WV
David Rider, EPA, Philadelphia, PA
Mike Robinson, OSM, Pittsburgh, PA
Craig Snyder, U.S.G.S. - BRD, Kearneysville, WV
Jay Stauffer, The Pennsylvania State University, University Park, PA
Don Stump, OSM, Pittsburgh, PA
Bernard Sweeney, Stroud Water Research Center, Avondale, PA
Cindy Tibbott, FWS, State College, PA
J. Bruce Wallace, University of Georgia, Athens, GA
John Wirts, WV DEP, Charleston, WV
John Young, U.S.G.S. - BRD, Kearneysville, WV

About the Presenters . . . .

Larry Emerson is Director of Environmental Performance with Arch Coal, Inc., in Huntington, West Virginia. He has a Bachelors degree in Agronomy from Virginia Tech (1978) and has been in the coal mine reclamation and environmental compliance field for 21 years. His professional affiliations include membership in the West Virginia Association of Professional Soil Scientists and the American Society for Surface Mining and Reclamation.

Denis Newbold is a Research Scientist at the Stroud Water Research Center where he studies nutrient cycling, organic particle transport, and riparian zone influences in stream ecosystems. He received a B.S. in engineering from Swarthmore College in 1971, an M.S. in hydrology from Cornell in 1973, and a Ph.D. in aquatic ecology from the University of California in 1977. From 1977 through 1983 Denis worked in the Environmental Sciences Division at Oak Ridge National Laboratory, where he was involved in both theoretical development and experimental analysis of the nutrient spiraling concept. Since joining the Stroud Center (then part of the Academy of Natural Sciences of Philadelphia) in 1983, his work has included modeling temperature influences on insect life histories, experimental studies of the spiraling of dissolved and particulate organic carbon, and investigations of the role of riparian forest buffers in mitigating nonpoint source pollution.

Jay R. Stauffer, Jr., has been working on the systematics, ecology, distribution, and behavior of stream fishes for more than 25 years. He received his B.S. from Cornell and his Ph.D. from Virginia Polytechnic Institute and State University. He co-authored a text on the Fishes of West Virginia, and is currently revising the Fishes of Pennsylvania. He has published some 140 articles in referred journals and is currently Professor of Ichthyology at the Pennsylvania State University.

Bernard Sweeney is presently Director, President, and Senior Scientist at the Stroud Water Research Center in Avondale, Pennsylvania, and an adjunct Professor at the University of Pennsylvania. The Stroud Center was founded in 1967 and is focused on producing new knowledge, greater understanding, and better appreciation of streams, rivers, and their watersheds through programs emphasizing basic and applied research and environmental education. Bernard has a Ph.D. from the University of Pennsylvania (1976) in Zoology and has published research papers on the following topics: Population and community ecology of aquatic invertebrates, the role of streamside forests in the structure and function of stream and river ecosystems, the effects of global warming on stream ecosystems, genetic variation and gene flow among populations of stream insects, factors affecting the growth and development of aquatic insects, bioenergetics and secondary production of aquatic insects, and the bioassay of toxic materials in aquatic systems.

J. Bruce Wallace received his B.S. from Clemson University, and M.S. and Ph.D. from Virginia Tech. He is currently Professor of Entomology and Ecology, University of Georgia, Athens, Georgia, where he teaches courses in stream ecology, aquatic entomology, and immature insects. He has served as major professor of some 38 graduate students at Georgia. Dr. Wallace is author, or co-author, of some 150 scientific papers, including book chapters concerned with various aspects of stream ecology, or aquatic entomology. Much of his research during the past 25 years has been conducted on southern Appalachian streams at the Coweeta Hydrologic Laboratory (U.S. Forest Service) in western North Carolina and supported primarily by the National Science Foundation. His primary research areas include: linkages between streams and terrestrial ecosystems; role of aquatic invertebrates in stream processes; effects of disturbance and recovery of streams from disturbance; secondary production and aquatic food webs and energy flow; and organic matter dynamics in headwater streams. Dr. Wallace is a past president (1991-1992) of the North American Benthological Society. He was the recipient of the 1999 Award of Excellence in Benthic Science from the North American Benthological Society.

EXECUTIVE SUMMARY

Mountaintop mining is a form of strip mining that uses large equipment to access multiple coal seams across large tracts of land. The terrestrial landscape is dramatically altered, and streams are filled with overburden material. Over the last approximately 20 years, the size of individual operations has increased, as has the number of mountaintop removal mines, leading to public concern over the cumulative environmental and social impacts of this mining method across Appalachia.

To help assess the potential impact of stream filling activities on the aquatic ecosystem, a one-day invitational meeting was organized by the Pennsylvania Field Office of the U.S. Fish and Wildlife Service to discuss the value of headwater streams. The speakers focused on the description of the mining method and the headwaters environment in which it is carried out. Special emphasis was placed on the ecological context and importance of headwater streams within the larger aquatic ecosystem.

Larry Emerson (Arch Coal) provided an overview of large-scale mountaintop mining as it is practiced in West Virginia. The demand for low-sulfur coal is the purely economic force driving the increase in mountaintop mining. This mining method allows companies to recover 85 to 90 percent of the coal resource. Companies are able to use large-scale mining because of their ability to put together large, contiguous tracts of land in West Virginia. Production costs are primarily in moving rock. This mining method is best employed on coal seams within the Stockton level and above, in southern West Virginia. These areas have already been deep- and contour-mined in the past, so there are few untouched coal reserves remaining. The estimated life of large-scale mining in the state is about 15 more years.

Mr. Emerson stated that, in the creation of the post-mining topography, there is real potential for water resources to be maximized so that wetlands and stream channel areas with biotic communities can be created. In addition, there is a great potential for re-mining pre-SMCRA mine sites, reclaiming them and bringing them up to today's standards in the process.

Bruce Wallace (University of Georgia) has been studying headwater streams at the Coweeta Hydrologic Laboratory in western North Carolina for 30 years. He has conducted a number of experiments that demonstrate the reliance of stream biological communities on inputs from the surrounding forests. For example, when leaf litter was excluded from a stream, the primary consumer biomass in the stream declined, as did invertebrate predators and salamanders (there are no fish in these small streams; salamanders are the only vertebrate predators). Overall, leaf litter exclusion had a profound effect on aquatic productivity, illustrating the direct importance of terrestrial-aquatic ecotones. Other experiments illustrated the fact that, while invertebrates and microbiota in headwater streams are only a minute fraction of living plant and animal biomass, they are critical in the export of organic matter to downstream areas by converting leaf litter to fine particulate organic matter, which is much more amenable to downstream transport than the leaves themselves are. Organic matter transport to downstream reaches totals about 1 kg of export per meter length of stream on an annual basis, and comprises a large proportion of the food supply for invertebrate populations downstream, which in turn become food for fish populations.

Dr. Wallace raised the concern that stream thermal regimes, which can have important influences on microbial activity, invertebrate fauna and fish egg development, larval growth, and seasonal life cycles, may be affected by valley fills and sedimentation ponds at the base of the valley fills. In addition, with the documented increases in nitrogen deposition that are occurring in eastern North America, we need to understand what is happening to nitrate concentrations in streams emerging from valley fills.

Dr. Wallace expressed concern that this mining practice is eliminating first order streams with no requirement for pre-impact biological inventories. Streams in the southern Appalachian region have been found to harbor outstanding biological diversity, with rare species known to occur in only one or two springbrooks or seepage areas.

Bernard Sweeney (Stroud Water Research Center) provided insights into the value of headwater streams based on research in southeastern Pennsylvania that has been ongoing since 1968. The Center's Robin Vannote formulated what has become known as the "River Continuum Theory," which views the stream ecosystem as a continuum from the first order headwater streams down through the larger order rivers. Results from the first few years of research at the Center demonstrated that first order streams are both abundant and crucial to the overall function of the ecosystem.

Dr. Sweeney emphasized the relationship between streams and the surrounding terrestrial environment. As wet depressions in the landscape, leaves tend to blow across the forest floor and get stuck in the streams. Very little of this coarse organic material (leaves) is transported downstream; most is processed by living organisms. Streams flowing through grassy areas have much lower inputs of coarse organic material than streams flowing through forests; this is a concern regarding the concept of reconstructing streams in grassy reclamation areas. Different kinds of leaves (from different species of trees) affect the production and biomass of invertebrates. In addition, as precipitation percolates through leaves on the forest floor, it extracts organic compounds from the leaves, similar to the effect of steeping a tea bag in hot water. These dissolved organic compounds -- "watershed tea" -- are carried to the stream by groundwater and drive a major portion of the aquatic system's productivity.

The stream bottom is the crucial site of biological and biochemical activities in stream systems. About 32 percent of the total bottom area in the White Clay Creek watershed is in first order streams. High species diversity is typical of benthic invertebrate populations in small headwater streams. Densities of invertebrates are similar in small, first order streams and larger streams, but the fact that there is so much benthic area available in small streams, and there are so many of them, mean that collectively the headwaters account for abundant production in the system.

The turnover of benthic invertebrate species is high as you travel down through the river continuum; there are few species in the headwaters that also occur downstream in a large river. This raises the question of what happens if headwater streams are eliminated. If a species occurs only in first, second and third order streams, and the first and second order streams are eliminated, how long can the third-order population persist? Because human developments typically concentrate along third, fourth, and fifth order streams, this is where accidents will happen that destroy aquatic life. Recolonization would occur through organisms moving in from the upstream, smaller tributaries -- but only if the tributaries still exist.

Dr. Sweeney cautioned that the area of eastern West Virginia and western Virginia are hotspots of new species discovery, due to thermal diveristy, and the lack of glaciation which allowed time for species to evolve. The aquatic insects of this area haven't even been fully characterized yet, and we can't afford to destroy what we don't know.

Denis Newbold (Stroud Water Research Center) discussed Webster and Wallace's concept of nutrient spiraling, which is a way of assessing the effectiveness of an ecosystem at processing nutrients. The tighter the nutrient spiral, the more effective the ecosystem is at trapping and reusing organic matter and nutrients as you move downstream. The spiraling length is relevant to the mountaintop removal issue, because it gets at the question of where, if you're an organism living in a downstream ecosystem, your nutrients originated.

In a typical stream carbon cycle, much of the dissolved organic carbon (DOC) in a stream is refractory (it doesn't get used very fast, and is transported great distances downstream). On the other hand, a significant portion of the DOC is labile, and it cycles within the stream ecosystem. About half of the labile DOC produced within any given reach of stream will be utilized within that reach, while the remainder is passed to a larger downstream reach. The next reach (the next order stream) will have a proportionately longer turnover length. Each downstream reach uses a portion of the labile DOC passed from upstream, and passes the remainder downstream. The downstream transfer and utilization of carbon successively cascades downstream. Turnover lengths also vary depending on the type of material being transported. Very fine particulate organic matter can move 10,000 km downstream, generally putting it into the ocean; refractory can move even farther, and on its way it feeds larger streams, rivers, and estuaries. While there is a wide range of stream ecosystem efficiency, the median is about 50% regardless of the size of the watershed.

Dr. Newbold discussed a possible scenario for the organic content of streams emerging from the toe of a valley fill. Precipitation will pick up organic matter from the revegetated valley fill surface, percolate through the fill, and eventually emerge below the fill as water with low-concentration refractory, possibly even at concentrations similar to what would have been there without the fill. However, the stream emerging from the fill will be missing the labile dissolved and particulate organic matter that would have been produced by the stream that is now buried, and it is this labile portion, produced by the stream itself, that supports downstream metabolism.

Summarizing, Dr. Newbold explained that a significant portion of exported organic matter originates within the stream and is labile. Soil and riparian areas next to the stream are major sources of carbon, and the decomposition of litter and the primary production of material in the stream are also important sources of organic matter that get exported downstream. Most of the organic matter inputs to mid-order streams originated from first and second order streams; between 60 and 80% of the water feeding a fourth-order stream came from first and second order streams. If you're in a fourth order basin, and you eliminate the first and second order streams, you eliminate half of the water and drainage area and stream bed area to the downstream larger order.

Jay Stauffer (Pennsylvania State University) discussed eliminating headwater streams from the standpoint of fish populations that occur in these areas.

Dr. Stauffer discussed many factors that lead to speciation in fish in headwater streams. It is a common misconception that fish fauna are well-known, and that there are no unique fish present in the coalfields' headwater streams. In fact, many headwater streams have fish populations that have become isolated due to any number of causes, and minimal gene flow with the main population results in the development of new species. These species may occur only in one or two small streams, and nowhere else.

These streams may even support populations of migratory fish, such as lampreys. Other species may move into headwater streams at certain times of the year, but won't be found there at other times.

Dr. Stauffer discussed the concepts of ecosystem inertia and elasticity. Inertia concerns the ability of a stream to withstand stress before structural components of the ecosystem change. Headwater streams may only have two or three species of fish, so there is little functional redundancy built into the fish community. The loss of one species would mean the loss of one-third of the fauna, which is a structual change. This causes a more drastic impact on the ecosystem than it would if a species were lost in a larger stream that supported many species. Other factors, such as buffering capacity, or how close the stream is to a major ecological threshold -- such as thermal limits -- are involved in determining a stream's inertia.

The elasticity of the system considers such factors as whether or not there are epicenters nearby that could provide organisms to reinvade a damaged ecosystem. In many headwater streams with unique fish or invertebrate species, there simply are no epicenters from which recolonization can take place -- these organism may only occur in one place. These headwater streams are very fragile and have very low inertia, and their ability to recover from stress is probably compromised because they are so unique and so different. Dr. Stauffer argues that we should not be taking chances with streams that support genetically unique aquatic life, because we can't risk losing that genetic diversity.

Dr. Stauffer discussed the possibility of "recovery" of stream ecosystems by trying to recreate streams on the mine benches, stressing that the goals of the recovery effort must be clearly articulated in advance: Do we want the stream or ecosystem back to the way it used to be? Is it satisfactory if something can just live in the system? If something different lives in the system, is it satisfactory if it serves the same basic functions as the original?

Larry Emerson, Arch Coal, Inc., Huntington, West Virginia

I'd like to first, illustrate in schematics and photos the process of large-scale mountaintop mining as it's practiced today in West Virginia, with particular emphasis on valley fills, which seem to be the focus of all these efforts. Secondly, to point out the relative value of some of these reclaimed sites with respect to water resources, and also to emphasize the potential of some of these post-mining sites to have some water resource value. Also, to touch on the reality that some mountaintop mining operations in existence today are going in and remining previously-mined, pre-law sites, and there is yet additional potential to remediate past mining scars from back in the '40's and '50's. I also have a slide on the areal extent of mountaintop mining in West Virginia from the West Virginia Geological and Economic Survey. Also, I can offer some of our mines for consideration as sites to be studied during the process. Should they fit the criteria, we offer them for consideration.

With respect to Arch's West Virginia operations, we have four of the six largest mining complexes in West Virginia. These four sites have walking draglines -- the large-scale equipment which allows us to compete under today's economic conditions. Just so everyone understands, the reason for mountaintop mining in West Virginia today is purely economics and markets. Demand for low sulfur coal is driving the eastern coal market. The other large deposits of low-sulfur coal are in the Powder River Basin which is very cheap to produce, due to thick coal seams, some reaching 68 feet. West Virginia's seams are more like 4 - 6 feet. With mountaintop removal, we can recover 85 to 90 percent of that coal resource, whereas with other mining methods it's sometimes significantly less than that. It is the large-scale ability to put together contiguous leased tracts of land in West Virginia (and there are historical reasons for that) that have allowed this type of large-scale mining to take place.

This is a schematic showing a typical dragline operation in West Virginia. The analogy I like to make is with a layer cake. If you take a slice through these mountains, it's like a layer cake with the fudge icing being the coal seams and the sandstone and shale strata in between the coal seams representing the cake. Some of these mountains contain 11 - 12 coal seams, mostly oriented horizontally, but there is some localized roll and dip in the seams. The first stage in the mining operation is to clear the area of vegetation (usually the landowner is responsible for this stage). The upper elevations of the mountain are then drilled, blasted, and excavated to recover the first coal seam. That overburden is deposited in the only available, stable place to put it, which is in the adjacent valley. That process proceeds downward to the lower elevations until you reach a certain coal seam elevation where the dragline is then deployed. The dragline then excavates down to the bottom two coal seams. The function of the dragline is basically to pick up the rock strata from point A and moves it to point B. The dragline excavation moves laterally through the mountain, uncovering these coal seams. Smaller equipment extracts the coal. Reclamation follows with bulldozers, resculpting the area to its post-mining topography with some rolls and undulations. It is possible to do a fair amount of creation in terms of how you re-grade to the post-mining topography. There's real potential here for post-mining water resources to be optimized so that there can be some addition of stream channel areas with which there could be some biotic communities restored.

Here's how it works operationally, at the Catenary Mine in Kanawha County: The upper horizons are excavated with smaller equipment, such as loaders and trucks. Then the electric shovel excavates down through the middle horizons, uncovering one or more coal seams from the top downward. Finally the dragline is utilized to uncover the lower coal seams. The dragline and shovel only move rock. We're basically rock miners, because we move multiple cubic yards of rock to recover one clean ton of coal, so our production costs are mainly in moving rock. Finally, the overburden is re-graded and shaped to its post-mining topography, which can be gently rolling with undulations and watercourses that approximate the pre-mining topography. So it's in this post-mining topography where we have a real potential to put in basins, check dams, stream channels, to recreate water areas where you can capture rainwater, allow it to accumulate or pool up, and there's potential to create wetland resources.

Now for an explanation of valley fill construction, the first order of business is sediment control. You go into your permitted valley fill area and construct the sediment control structure, which is designed on the maximum amount of the disturbed watershed behind it. West Virginia requirements are 0.125 acre-feet of sediment storage capacity for each acre disturbed. The actual construction of the fill begins at the headwaters; the excavated rock material is placed first at the headwater areas, then progresses downstream. Proceeding on, this is your classic end-dump valley fill, where the larger rock, just by shear gravity and segregation, rolls down to the bottom, creating internal drainage through the fill. There are still going to be some perched aquifers on either side of the hollow, and there will also be some surface runoff -- this reality is accounted for in the design process and the result is that these structures are somewhat porous and there's a fair amount of infiltration. The big rocks that roll down to the bottom provide void spaces and places for water to be stored. When you reach the permitted extent of the valley fill, you put in post-mining sediment control and drainage ditches. These are generally 50-foot vertical lifts with 20-foot horizontal benches, with a certain percentage grade down to the center (this is the center core fill). Some fills are side drained fills, with groin ditches on each side (different fill design). The final stage requires certification by a registered professional engineer and revegetation.

During the active phase of mining, the area is open to the elements and weathering. This phase can run from 6 to 18 months in length. However, all surface runoff is channeled through a sediment control structure and regulated as a point source under the Clean Water Act. After final reclamation, the post-mining topography lends itself to re-creation of water resources. Ponds, basins, check dams, and bench sediment control structures are all designed to handle the surface runoff from predetermined rain events under the Surface Mining Act. It is with these structures that wetland resources could be created on the mine site.

There's also a lot of potential to remine previously mined areas (pre-law) -- these can be reclaimed and brought up to current standards. These examples are from the Catenary site. Old refuse fills that have been abandoned prior to 1977 can be capped over and reclaimed using modern mining methods [showed slide of reclaimed area]. Old slurry impoundments have been eliminated as part of the mitigation process; when some of these sites are reclaimed, current law allows mitigation credits. There are opportunities for creating wetlands for treating pre-law discharges. There's a substantial body of knowledge out there on re-creating wetlands, and there's lots of potential to do this on older mine sites.

This slide is another illustration of some of the post-mining water resources suitable for aquatic life. Some of them are even flowing. The top of a valley fill is shown on the slide, with a wide bench on the perimeter. SMCRA does not allow standing water on valley fills, but there are a lot of other areas of the reclaimed site that lend themselves very well to wetland resources. We can construct basins and settling ponds to capture rainfall, and over time infiltration occurs through the backstack that ultimately can provide a post-mining spring in certain limited circumstances. Another example is a perimeter ditch around the periphery of the mine site.

The Hobet 21 site was the first area to use a walking dragline in West Virginia, in 1983. We've had 15 years of large-scale mining at that site. The area now has over 50 valley fills. It lies in the upper Mud River drainage. This site may provide opportunities for study.

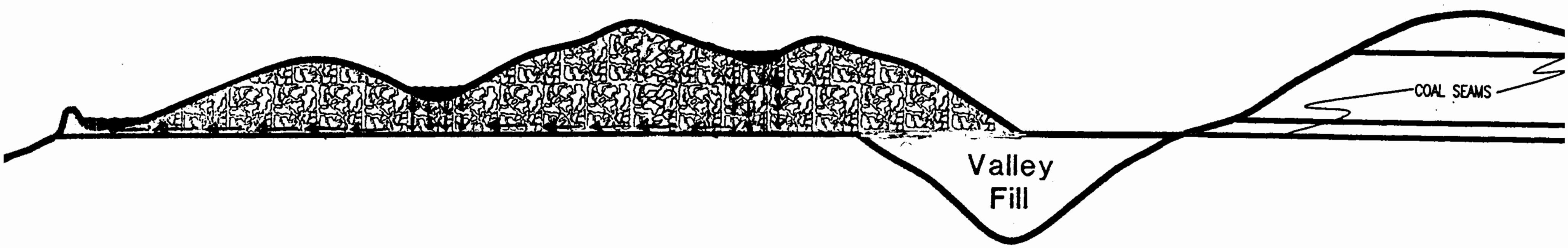
This overhead (Figure 1) reinforces the concept of back-filled areas and valley fills to present opportunities for post-mining water resources. We have found through experience that valley fills are porous in nature and water becomes stored within the fill. This stored water is continuously released to the receiving stream, and provides significant flow during extended dry periods.

This overhead (Figure 2) shows a typical cross section of a valley fill, using center core construction method, where you're dumping from the headwaters and on each side laterally as this is constructed from the headwaters on down to the mouth. As you can see, the larger rocks roll to the center and to the bottom and creates that porous area. There is water flowing from the toe of these areas. With regard to the backfill areas, this overhead represents the undisturbed solid area just below the lowest coal seam that was mined. This barrier acts as an aquaclude and prevents the downward infiltration of water. As we construct basins, channels, and ponds on top, some water infiltrates, reaches the shale underlying the lowest coal seam, and stops there and flows down-gradient and pops out at the toe of one of the outslopes, and in several occasions there is flowing water coming out of these sites.

KINKAID -- DEFINE BACKFILL. EMERSON -- BACKFILL IS ROCK STRATA THAT IS REMOVED DURING THE MINING PROCESS TO UNCOVER THE COAL SEAM, AND IS DEPOSITED ON TOP OF THE SOLID BENCH WHICH IS REPRESENTED AS THE HORIZONTAL DISTANCE FROM ONE SIDE OF THE MOUNTAIN TO THE OTHER. BY CONTRAST, THE VALLEY FILL MATERIAL IS DEPOSITED ADJACENT TO THE BENCHED BACKFILL AREA (SEE DRAWING). BACKFILL IS COMPOSED OF SANDSTONE, SHALE AND OVERBURDEN, OR INTERBURDEN WHICH IS ROCK FROM IN BETWEEN COAL LAYERS. THIS MATERIAL IS PICKED UP BY THE DRAGLINE AFTER IT'S BEEN DRILLED OR BLASTED, THE DRAGLINE TURNS AROUND 90 DEGREES, AND DEPOSITS THE MATERIAL SOME 200 FEET TO THE SIDE. THIS "SPOIL PILE" IS THEN RESCULPTED TO ITS POSTMINING

EXPLANATION

Backfill Material
Water Percolation Path
Undisturbed Rock Strata (barrier to downward percolation of water)
Direction of Groundwater Flow



REGRADED SECTION OF BACKFILL ON SOLID BENCH
Backfilled rock material is very permeable and allows rainwater to percolate through and become stored as groundwater. This new recharge area then becomes the source of water for post mining streams and seeps.

FIGURE 1.

Typical Cross Section Of Finished Valley Fill

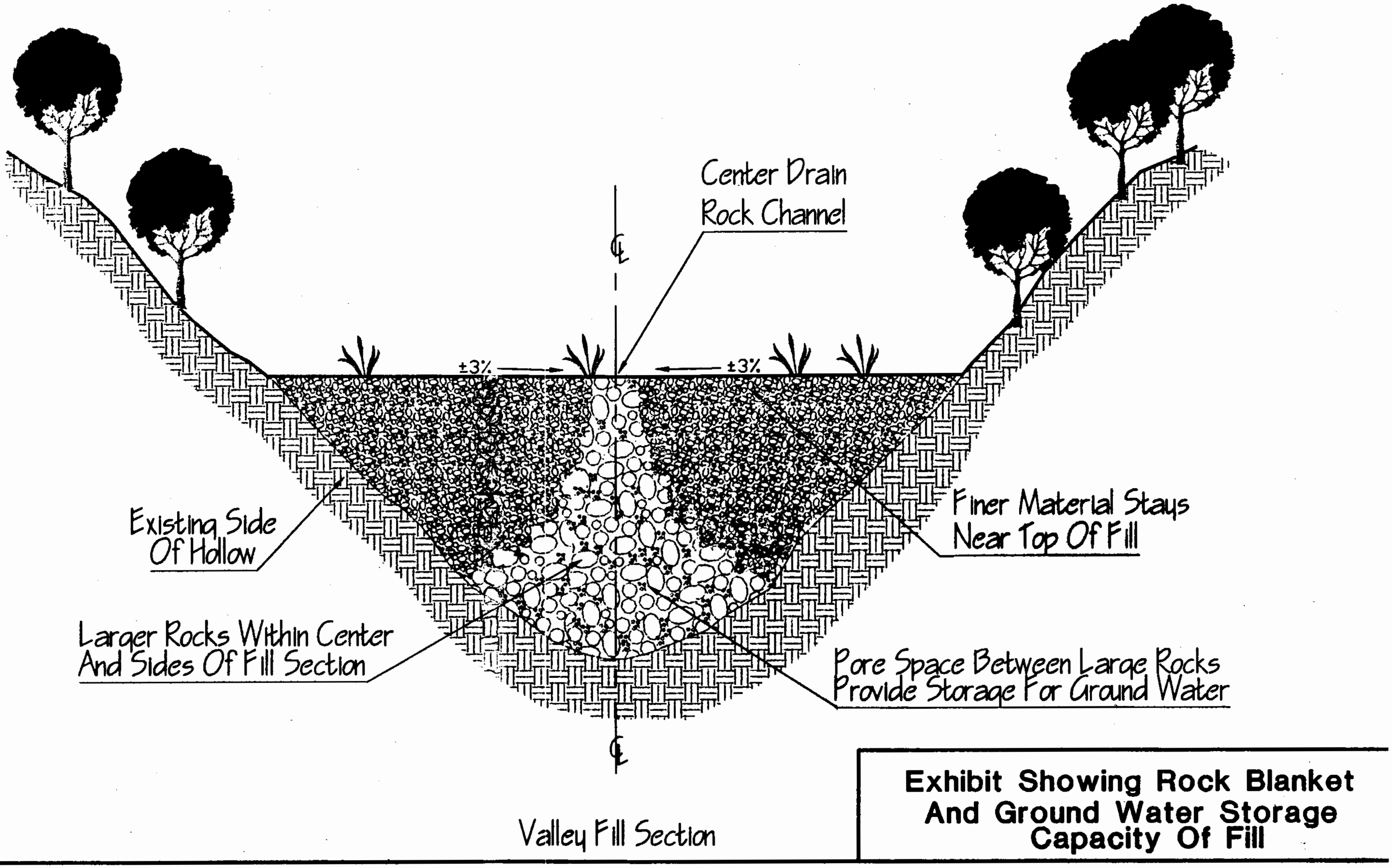


FIGURE 2.

TOPOGRAPHY. **KINKAID** - IS IT COMPACTED OR JUST DROPPED? **EMERSON** - IN THE CASE OF THE DRAGLINE EXCAVATION, IT'S JUST DROPPED. WITH RESPECT TO COMPACTION, THERE'S SOME COMPACTION GOING ON WHEN YOU'RE RESCULPTING THIS, WHEN YOU PUT A DOZER ON THERE. REMEMBER THE SPOIL PILES ARE FAIRLY SHARP WHEN YOU FIRST DEPOSIT THEM, THEN YOU PUT BULLDOZERS ON THEM TO SHAPE THEM OFF, MAKE THEM SMOOTHER, AND PREPARE THE SEED BED. THERE'S AT LEAST SOME COMPACTION THAT GOES ON THERE WHEN YOU HAVE THE BULLDOZERS RESHAPING.

KINKAID - WITH SANDSTONE AND SHALE, THERE IS SOME POTENTIAL FOR ACID LEACHING, GIVEN THE COMPOSITION OF THE 5 BLOCK COAL. WHAT IS PUT ON THE SURFACE FOR REVEGETATION? **EMERSON** - SOMETIMES, TO THE EXTENT NATIVE SOILS CAN BE SALVAGED AND REDISTRIBUTED, THAT HAPPENS, BUT THAT'S MORE AN EXCEPTION RATHER THAN THE RULE. THERE IS A PROVISION IN THE REGULATIONS THAT ALLOWS FOR AN ALTERNATE TOPSOIL MATERIAL TO BE USED IF CAN BE TESTED AND SHOWN TO BE THE "BEST AVAILABLE" THAT IS WITHIN THE STRATA. IF IT'S TESTED AND SHOWN TO HAVE GOOD SOIL MEDIUM CHARACTERISTICS AND YOU PUT TOGETHER A HANDLING PLAN THAT SHOWS HOW YOU RECOVER THOSE PARTICULAR STRATA AND USE THEM AS SOIL MEDIUM, THIS TENDS TO BE THE RULE: WE'RE BASICALLY CREATING NEW TOPSOILS FROM SHALE AND SANDSTONE THAT EXISTS WITHIN THE MOUNTAIN PRIOR TO MINING. IT'S BEEN OUR EXPERIENCE THAT IT'S VERY CALCAREOUS IN NATURE (PASTE pH BETWEEN 6.5-7.5), WITH A FAIR AMOUNT OF CALCIUM AND MAGNESIUM, WHICH DOES CERTAINLY INCREASE THE TDS OF POST-MINING WATER QUALITY. THERE'S NO DOUBT ABOUT THAT. IT DOES INCREASE THE BUFFERING CAPACITY AS WELL.

KINKAID - YOU'RE PLACING SOIL OVER THE VALLEY FILL AND BACKSTACK MATERIAL? **EMERSON** - YOU MEAN SALVAGING NATIVE TOPSOILS? **KINKAID** - I'M WONDERING WHAT'S ON TOP OF THE BACKSTACKED MATERIAL AND VALLEY FILL FOR THINGS TO GROW? **EMERSON** - IT'S GENERALLY A MIXTURE OF SANDSTONE AND SHALE THAT'S IN THE INTERVAL BETWEEN THE 5 BLOCK AND STOCKTON FORMATIONS WHICH IS A MIXTURE THAT WINDS UP ON TOP OF THE SPOIL PILE AS A RESULT OF THE EXCAVATION. WE HAVE FOUND THAT SINCE pH IS FAIRLY HIGH AND THE MATERIAL WEATHERS FAIRLY READILY, THAT PARTICLE SIZE DISTRIBUTION, ALTHOUGH FAIRLY SANDY, STARTS TO APPROACH LOAM IN MOST CASES. WE ADD NITROGEN, PHOSPHOROUS, AND POTASSIUM AND SEED MIXTURE, MOSTLY THROUGH HYDROSEEDING. IT ACTUALLY GROWS HERBACEOUS COVER VERY WELL. WHAT GOES ON THERE IS PART OF THE PROCESS OF EXCAVATING THE MATERIAL. AFTER THE STRATA HAS BEEN BLASTED AND RE-HANDLED, YOU PUT THE BULLDOZERS ON TO RE-SCULPT IT, YOU GET A FAIR AMOUNT OF FINE MATERIAL DURING THE PROCESS. WE THEN SPRAY OUR MIXTURE OF GRASSES, LEGUMES, FERTILIZERS AND MULCH AND IT GROWS THAT GRASS/LEGUME MIXTURE VERY WELL. SO OVER TIME YOU'RE BASICALLY CREATING A NEW SOIL AS A RESULT OF USING THIS BRAND-NEW PARENT MATERIAL. **KINKAID** - DO TREES GET ESTABLISHED? TREES ARE HAND-PLANTED AFTER HERBACEOUS COVER IS ESTABLISHED, BECAUSE OF EROSION CONTROL REQUIREMENTS. THAT DOES PRESENT SOME PROBLEMS IN GETTING TREES ESTABLISHED QUICKLY. WE HAVE FOUND THAT PIONEER SPECIES TEND TO COMPETE WELL WITH GRASSES AND THEY HAVE AN EDGE OVER NATIVE HARDWOODS. GENERALLY POPLARS, MAPLES, ASH, BIRCH, BLACK CHERRY, ETC., WILL GROW FAIRLY WELL AND COMPETE WITH THE GRASSES AND LEGUMES THAT ARE ALREADY ESTABLISHED. IT'S GENERALLY MUCH MORE DIFFICULT TO ESTABLISH HARDWOODS. WE HAVE FOUND THAT BY GOING TO OLDER SITES THAT WERE MINED IN THE MID-70S, ON THE OUTSLOPES WHERE MATERIALS WERE PUSHED OVER AND NOT COMPACTED, AND NOT ANY KIND OF POST MINING SEEDBED PREPARATION TOOK PLACE, WHERE IT'S LEFT LOOSE AND ROUGH -- THOSE GENERALLY WERE MUCH MORE CONDUCIVE TO NATURAL SUCCESSION OF HARDWOODS ONTO THESE SITES. ON TOP OF THE OLDER 20-YEAR OLD SITES, WHERE THERE WAS A FAIR AMOUNT OF COMPACTION, NATIVE TREES HAD A HARDER TIME. SO COMPACTION PLAYS IN A ROLE IN THAT.

KINCAID - WHEN MATERIALS ARE RELOCATED TO VALLEY FILL AND BACKSTACK LOCATIONS, HOW ARE THEY CHARACTERIZED AS TO ACID-BASE ACCOUNTING AND THE PHYSICAL CHARACTERISTICS OF THE ROCK -- WHAT ABOUT THE MATRIX WHICH CEMENTS THE SANDSTONE. IS THE MATRIX SUBJECT TO ATTACK BY NATURAL WATERS OR WATERS THAT MAY BE ALTERED AS A RESULT OF FLOW-THROUGH? **EMERSON** - THERE'S A FAIR AMOUNT OF PREMINING GEOLOGIC CHARACTERIZATION DURING THE APPLICATION PROCESS. CORES ARE DRILLED PRIOR TO MINING, AND ALL OF THE ROCK STRATA GO THROUGH AN ACID-BASE ACCOUNTING TO DETERMINE THE ACID-PRODUCING POTENTIAL FOR EACH STRATA. THERE IS A NET BALANCE DETERMINED TO DETERMINE WHETHER STRATA IS A NET NEUTRALIZER OR NET ACID PRODUCER. IF YOU FIND AREAS THAT ARE NET ACID PRODUCERS, YOU HAVE TO SPECIAL HANDLE THOSE LAYERS OF ROCK AND SEGREGATE THOSE AND HANDLE THEM THROUGH A SPECIAL HANDLING PLAN. GENERALLY, IN SOUTHERN WEST VIRGINIA, THESE HAVE BEEN DESCRIBED BY GEOLOGISTS AS MARINE DEPOSITS AND IN MOST CASES ARE CALCAREOUS. THE MATRIX IS CALCIUM CARBONATE BASED; NOT LIMESTONE, BUT IT DOES HAVE A FAIR AMOUNT OF CALCAREOUS MATERIAL AS A CEMENTING AGENT. THE SHALES TEND TO BREAK DOWN READILY WITH WEATHERING

AND ARE ALSO CALCAREOUS IN NATURE, SO IN MOST CASES THERE IS RAPID DETERIORATION OF THE STRUCTURE, FORMING A FAIR AMOUNT OF SAND- AND SILT-SIZE MATERIALS FOR PLANT GROWTH.

KINKAID - IT WOULD SEEM THESE MATERIALS COULD CRUMBLE IN A WAY THAT COULD AFFECT SLOPE AND STABILITY OF THE FILL. **POLITAN** - WE HAVE DURABLE ROCK TESTS, TOO. FOR DURABLE ROCK FILLS, THEY HAVE TO PASS CERTAIN TESTS TO BE PLACED IN A VALLEY FILL. **EMERSON** - SLAKE DURABILITY TESTS ARE DONE ON MATERIALS THAT ARE GOING TO BE PLACED IN THE VALLEY FILLS; THEY HAVE TO STAND UP TO A CERTAIN AMOUNT OF ABRASION AND WEATHERING. IF THEY PASS THE SLAKE TEST, YOU'RE ALLOWED 80% DURABLE ROCK IN FILLS. REGARDING STABILITY OF THE BACKFILL, THE SLOPES ARE NO GREATER THAN 2:1 AND IN MOST CASES ARE MORE GENTLE SLOPES POST-MINING THAN PRIOR TO MINING. **KINKAID** - SO VALLEY FILLS HAVE STEEPER SLOPE? **EMERSON** - THE FACES OF THE VALLEY FILL ARE STAIR-STEPPED, AND THERE ARE ENGINEERING CALCULATIONS WHICH GO INTO SAFETY FACTORS WHICH DETERMINE THE FINAL SLOPE OF THE FACE, AND FOUNDATION STUDIES ARE DONE PRIOR TO MINING. YOU KNOW WHERE THE VALLEY FILL IS GOING, YOU KNOW WHAT THE SUBSOILS ARE IN THE CRITICAL AREA DOWN AT THE TOE, WHICH IS THE MOST IMPORTANT AREA TO BE AWARE OF, AND THERE ARE SOIL TESTS DONE THERE TO MAKE SURE IT HAS THE BEARING CAPACITY TO SUPPORT THESE STRUCTURES. INTERNAL DRAINAGE OF THESE STRUCTURES IS ALSO DESIGNED INTO THEM. ALL THAT IS LOOKED AT IN THE APPLICATION PROCESS AND REVIEWED, AND IF IT MEETS CERTAIN SAFETY CONSIDERATIONS, THEN THAT PARTICULAR CONFIGURATION IS PERMITTED. **KINKAID** - ARE TESTS DONE THAT RELATE TO LONG-TERM GEOCHEMICAL STABILITY OF THE FILL MATERIAL? **EMERSON** - IF IT MEETS THE SAFETY FACTORS, IT IS PRESUMED IT WILL BE STABLE LONG-TERM. (CONCERNING REFUSE FILLS AND SLURRY IMPOUNDMENTS, ADDITIONAL SAFETY FACTORS ARE ENGINEERED, E.G., EARTHQUAKE FACTORS.) VALLEY FILLS HAVE BEEN CONSTRUCTED IN THE SOUTHERN PART OF THE STATE FOR OVER 20 YEARS AND TO MY KNOWLEDGE THERE HAS NOT BEEN A SINGLE DOCUMENTED FAILURE OF ANY OF THESE STRUCTURES. THERE MAY HAVE BEEN A FEW MINOR SLUFFS AT THE FACE OF THE FILLS, BUT NO DOCUMENTED FAILURES, PRIMARILY BECAUSE OF THE SAFETY FACTORS INVOLVED IN THE ENGINEERING AND PRE-MINING PERMITTING REQUIREMENTS. **KINKAID** - SO IT WOULD BE FAIR TO SAY THAT THE EXISTING REGULATIONS ADDRESS THE PHYSICAL, MECHANICAL STABILITY. **EMERSON** - THAT WOULD BE A FAIR STATEMENT, YES.

With respect to the areas in West Virginia that are susceptible to, or available for large-scale mining, the West Virginia Geologic and Economic Survey has issued a report to the Governor's Task Force last October that indicated that most of the large-scale mountaintop mining takes place in the Allegheny and upper Kanawha formations, which have a geographic extent within the State where the coal seams lie relatively close to the top and are conducive to this type of mining (Figure 3). With respect to what can be mined using these methods, it's generally from the Stockton level up. In a few cases you can surface mine the Coalburg, but generally it's a deep mine. Everything below that is either below drainage or too deep to be economically recoverable with large-scale surface mining.

Regarding the areal extent, the Geologic Survey mapped southern West Virginia -- the elevation of coal seams are proximate enough to the top of the mountains so it's potentially viable economically (Figure 4). Keep in mind these areas have been extensively deep-mined and contour-mined in the past. Over the long run, there are not many untouched coal reserves remaining; we think existing operations could go for another 15 to 20 years and then large-scale mining, by economic forces and depletion of reserves, will cease to exist as viable mining method.

DENSMORE - THE AREA YOU SHOW THERE IS AREAS OF MOUNTAINTOP REMOVAL MINING PRIMARILY? **EMERSON** - THAT'S CORRECT. **DENSMORE** - IF YOU LOOKED AT ALL SURFACE MINING (NOT JUST MOUNTAINTOP REMOVAL) THAT MIGHT INVOLVE VALLEY FILLING AND THEREFORE HEADWATER STREAMS/AQUATIC IMPACTS, HOW BIG AN AREA WOULD WE BE TALKING ABOUT? **EMERSON** - IF YOU LOOK AT CONTOUR MINING, WHERE YOU JUST TAKE A SLICE OUT OF THE SIDE OF THE MOUNTAIN AND FOLLOW THE OUTCROP AROUND THE MOUNTAIN, YOU COULD GO MUCH FARTHER INTO THE CENTRAL AND SOUTHERN AREA OF STATE, PERHAPS AS FAR NORTH AS CLAY AND BRAXTON COUNTIES. BUT BEAR IN MIND THAT THE "HINGE LINE," NORTHERN PART OF THE STATE HAS HIGHER-SULFUR RESERVES, WITH SOUTHERN WEST VIRGINIA HAVING THE LOW-SULFUR RESERVES. SO MOST OF THE DEMAND IS IN SOUTHERN WEST VIRGINIA BECAUSE OF THE CLEAN AIR ACT, OTHERWISE THE COAL NEEDS TO GO TO PLANTS WITH SCRUBBERS.

ROBINSON - DOES ARCH HAVE LONG TERM PLANS ON RESERVES FOR THIS 15-YEAR PERIOD? IS THERE DATA TO SUPPORT THIS? **EMERSON** - WE DON'T OWN THE LAND, IN MOST CASES WE LEASE. THESE ARE LARGE TRACTS OF

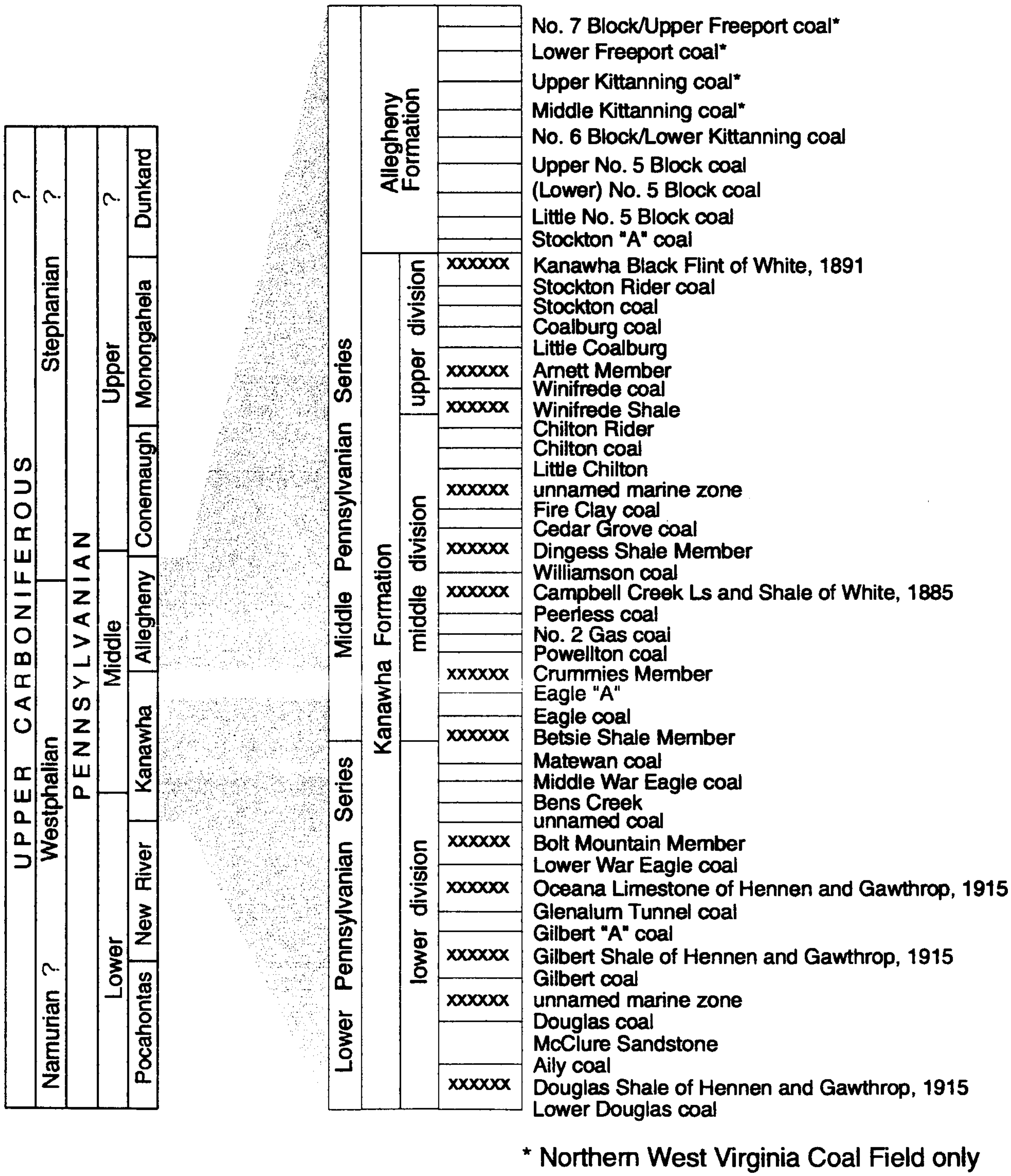
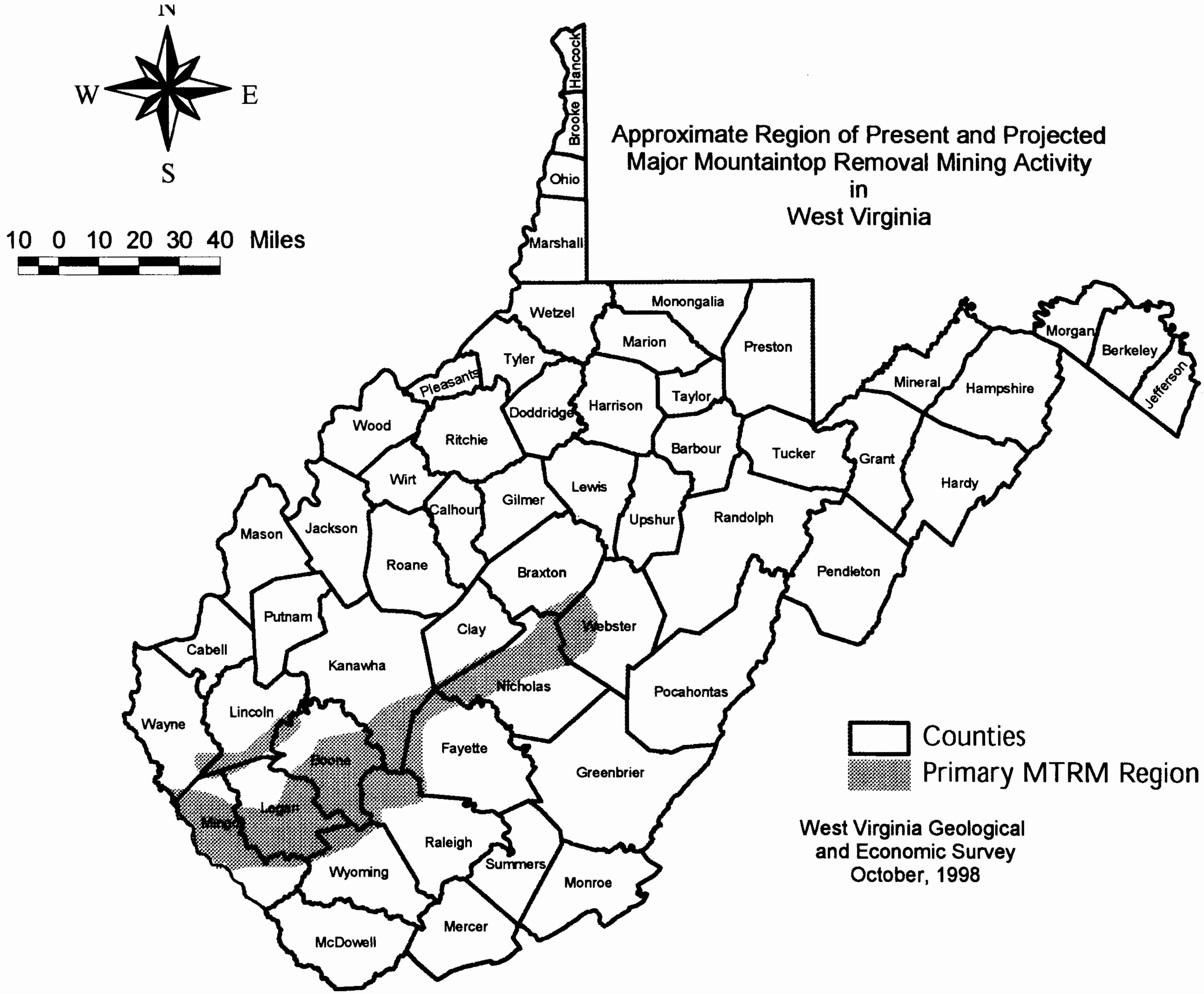

UPPER CARBONIFEROUS ?
Namurian ?
Westphalian
Stephanian ?
PENNSYLVANIAN
Lower
Middle
Upper ?
Pocahontas
New River
Kanawha
Allegheny
Conemaugh
Monongahela
Dunkard
Lower Pennsylvanian Series
Middle Pennsylvanian Series
Kanawha Formation
Allegheny Formation
lower division
middle division
upper division
No. 7 Block/Upper Freeport coal*
Lower Freeport coal*
Upper Kittanning coal*
Middle Kittanning coal*
No. 6 Block/Lower Kittanning coal
Upper No. 5 Block coal
(Lower) No. 5 Block coal
Little No. 5 Block coal
Stockton "A" coal
xxxxxx Kanawha Black Flint of White, 1891
Stockton Rider coal
Stockton coal
Coalburg coal
Little Coalburg
xxxxxx Arnett Member
Winifrede coal
xxxxxx Winifrede Shale
Chilton Rider
Chilton coal
Little Chilton
xxxxxx unnamed marine zone
Fire Clay coal
Cedar Grove coal
xxxxxx Dingess Shale Member
Williamson coal
xxxxxx Campbell Creek Ls and Shale of White, 1885
Peerless coal
No. 2 Gas coal
Powellton coal
xxxxxx Crummies Member
Eagle "A"
Eagle coal
xxxxxx Betsie Shale Member
Matewan coal
Middle War Eagle coal
Bens Creek
unnamed coal
xxxxxx Bolt Mountain Member
Lower War Eagle coal
xxxxxx Oceana Limestone of Hennen and Gawthrop, 1915
Glenalum Tunnel coal
Gilbert "A" coal
xxxxxx Gilbert Shale of Hennen and Gawthrop, 1915
Gilbert coal
xxxxxx unnamed marine zone
Douglas coal
McClure Sandstone
Aily coal
xxxxxx Douglas Shale of Hennen and Gawthrop, 1915
Lower Douglas coal
* Northern West Virginia Coal Field only

FIGURE 3.



N
W
E
S
10 0 10 20 30 40 Miles
Approximate Region of Present and Projected
Major Mountaintop Removal Mining Activity
in
West Virginia
Hancock
Brooke
Ohio
Marshall
Wetzel
Monongalia
Marion
Preston
Tyler
Pleasants
Wood
Ritchie
Doddridge
Harrison
Taylor
Barbour
Tucker
Mineral
Hampshire
Morgan
Berkeley
Jefferson
Grant
Hardy
Wirt
Calhoun
Gilmer
Lewis
Upshur
Randolph
Mason
Jackson
Roane
Braxton
Pendleton
Putnam
Clay
Webster
Cabell
Kanawha
Nicholas
Pocahontas
Wayne
Lincoln
Fayette
Boone
Greenbrier
Logan
Mingo
Raleigh
Wyoming
Summers
Monroe
Mercer
McDowell
Counties
Primary MTRM Region
West Virginia Geological
and Economic Survey
October, 1998

FIGURE 4.

10,000 - 15,000 ACRES. WE HAVE SOME CORE DRILLING DATA ON RESERVES THAT INDICATE 10 TO 15 YEARS OF RESERVES USING LARGE-SCALE EQUIPMENT UNDER PRESENT ECONOMIC CONDITIONS.

POMPONIO - ARE SEAMS BENEATH THE STOCKTON BEING MINED? **EMERSON** - YES, DEEP, CONTOUR AND AUGER MINING ARE ALSO GOING ON.

HARTOS - WHAT TYPE OF SITE CONSTRUCTION CRITERIA GO INTO PLANNING A VALLEY FILL? **EMERSON** - THAT'S A VERY LARGE QUESTION AND WOULD TAKE LOT OF TIME. I COULD IDENTIFY THOSE AREAS FOR YOU LATER.

Dr. Bruce Wallace, Department of Entomology and Institute of Ecology, University of Georgia, Athens, Georgia

The problem here, as I see it, is that it is a difficult question how much headwaters need to be protected to really ensure integrity of downstream reaches (Figure 1). The problem is that we stream ecologists study one or two streams, maybe adjacent waters, or streams in longitudinal linkage. Rarely do we look at drainage networks. I have been working for 28 to 30 years at the Coweeta Natural Research Laboratory in western North Carolina. The Coweeta basin is slightly larger than the controversial Pigeonroost watershed. Over the years we've studied a number of things at Coweeta, such as replacing hardwoods with conifers; we've done some clearcutting experiments to study the response of the stream to clearcutting.

Oñe of the things that I hope to convince you is that there are some things happening in headwater streams that are important, some of the processes there are important, some invertebrates are important and some of the things they do are important. First of all, is the reliance of the stream community on inputs from surrounding forests. One of the ways we've been testing this hypothesis for a number of years is by a litter exclusion project, where we've constructed a canopy over an entire reach of a headwater stream which excludes terrestrial litter inputs so we can see what happens to stream productivity. We also have lateral fences along the sides to keep lateral movement of terrestrial organic matter out of the stream. So we're looking at linkages between invertebrates and what's happening in the stream with detrital inputs from the forest. These detrital inputs are very important to the biology of the stream. The question we're testing is: What happens if this linkage is broken or severely curtailed (we can't eliminate all inputs to the stream). How dependent are these headwater stream invertebrates on detrital inputs? Are detritivores, as a group, food limited (Figure 2).

This slide shows the standing crop of detritus in the stream from the start of treatment (litter exclusion) over 1,460 days (Figure3). The treatment stream has a large amount of stored detritus in it, and has been losing detritus at a rate of about 0.8 grams/m^2/day for the first 4 years of this experiment. So these streams are very retentive, they have a lot of detritus in them and store a lot of material.

This slide shows a reference stream with a lot of leaf material. The next slide shows a litter-exclusion stream, where we've actually excluded the terrestrial inputs to the stream. There's little, in fact hardly any, litter in the stream. We still have large, woody debris in the stream which we removed last summer, so I don't have all those data complete for the past year. However, I do have the results of four years of litter exclusion (Figure 3) which included one year

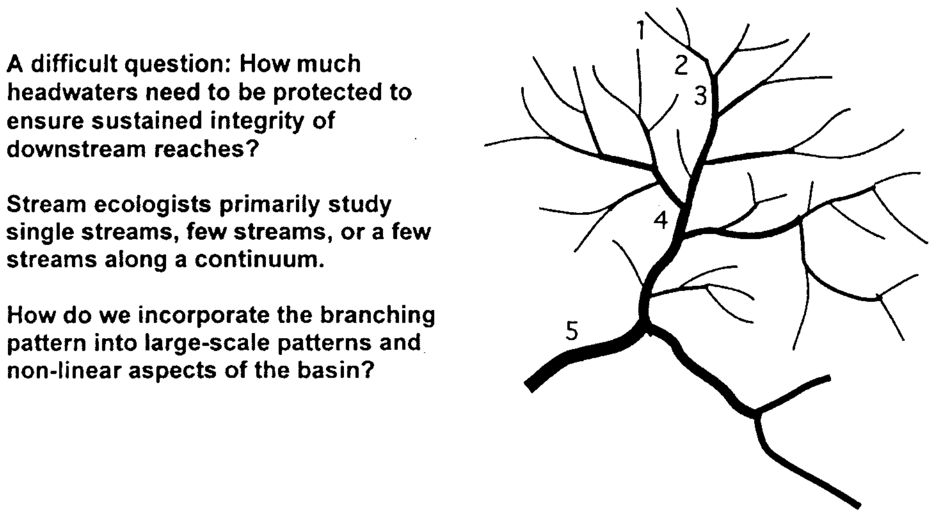
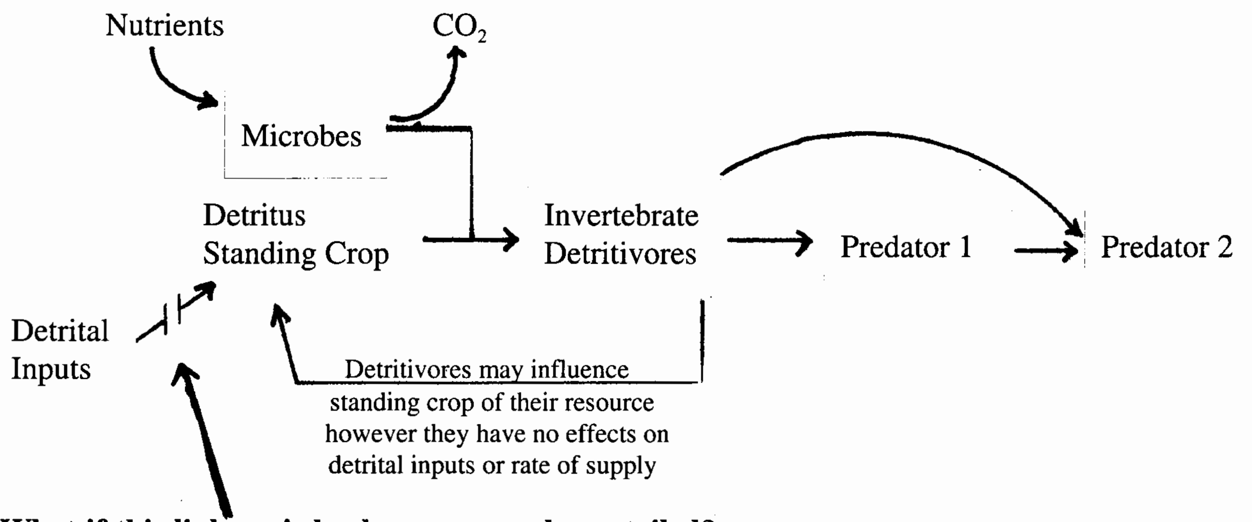


FIGURE 1.



What if this linkage is broken or severely curtailed?
How dependent are headwater stream invertebrates on detrital inputs?
Are detritivores as a group, food limited?
What type(s) of currency do we use to measure invertebrate response?

FIGURE 2.

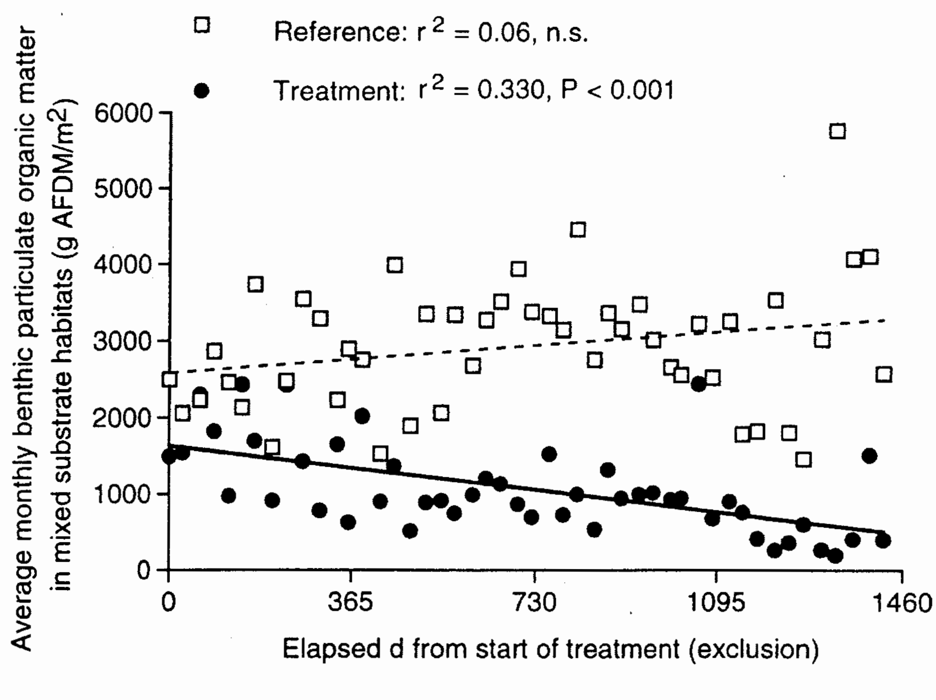


FIGURE 3.

of removal of small woody debris, which decomposes very slowly. What we found was, after we excluded the litter input, that we still had this woody debris which still served as a food resource to certain invertebrates; a few of them were able to switch over to use the biofilm which accumulates on the wood as a food resource.

This slide shows total primary consumer biomass for the first 365 days (pretreatment), during three years of litter exclusion, and during the period of small woody debris removal plus litter exlusion (Figure 4). You can see what's happening to invertebrate biomass: the primary consumer biomass is going down whereas the reference stream biomass remained basically the same. (There was one treatment stream and one reference stream used in this study. We can get away with that by using a randomized intervention analysis technique which uses extensive pretreatment period data compared with post-treatment.)

We also saw a decrease in invertebrate predators and salamanders over time (Figure 5). (There are no fish in these streams; salamanders are the only vertebrate predators.)

I want to point out that there are a couple of functional groups of invertebrates that are very directly dependent on this allocthonous input. One is the shredders, another the gatherers, in fact the primary consumers as a group, invertebrate predators, and this carries all the way up to the salamanders -- significant decreases.

These data are for the mixed substrate habitat, which represents about 87% of the stream area. On the other hand, you have high gradient bedrock substrates, which are dominated primarily by scrapers, filterers, some gatherers, some shredders (Figure 6). No change in abundance or biomass over time occur on the bedrock habitat, suggesting a somewhat different food web that relies on transported organic matter rather than on material that's actually stored there as benthic organic matter through time.

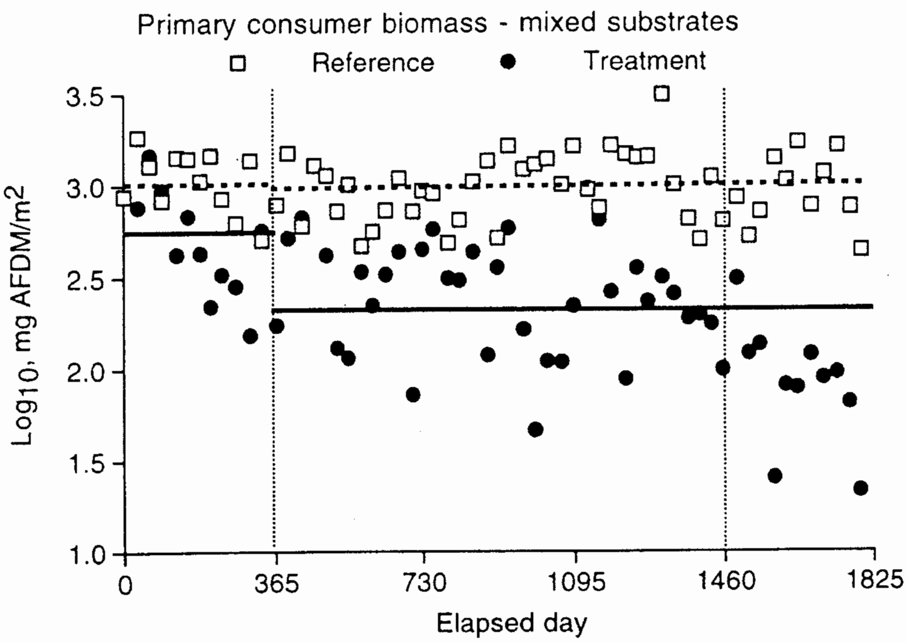


FIGURE 4.

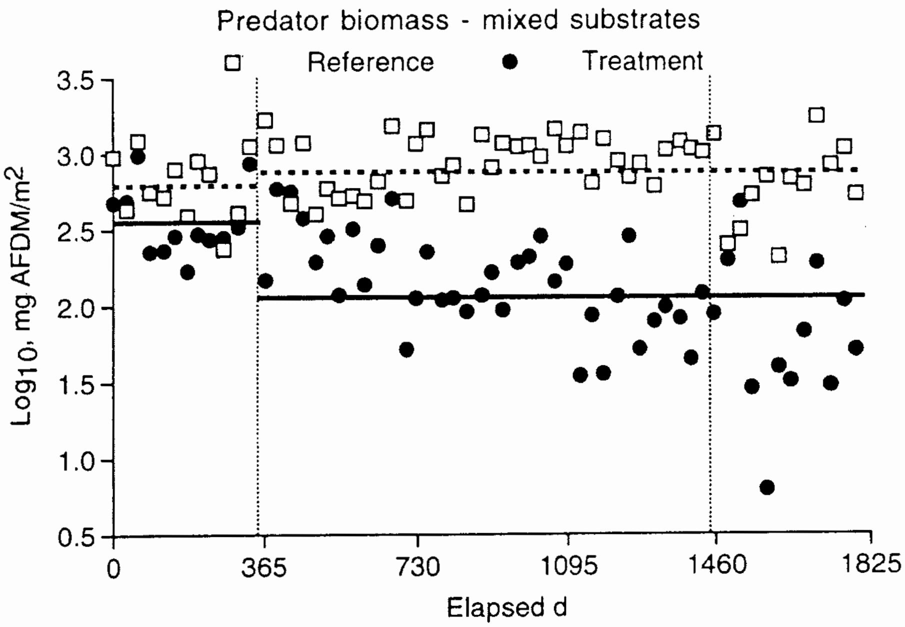


FIGURE 5.

FIGURE 6.

Randomized Intervention Analysis testing probabilities of change between reference and treatment stream for benthic abundance and biomass. Values are probabilities that observed differences were significant.

	-------- Mixed substrates --------		---- Bedrock substrates ----	
Group	- Abundance -	- Biomass -	-Abundance-	- Biomass -
Scrapers	0.408	0.670	0.782	0.822
Shredders	<0.0000001	0.012	0.400	0.574
Gatherers	<0.0000001	0.001	0.752	0.994
Filterers	0.174	0.326	0.227	0.916
Primary consumers	<0.0000001	0.006	0.863	0.612
Invert. Predators	<0.0000001	<0.0000001	0.317	0.399
Salamanders	0.009	0.010	1.000	0.863

We had a period of five pre-treatment years, and if we examine total secondary production vs. predator production in that pre-treatment period, you can still see a relationship (Figure 7). A lot of that is related to nothing more than the storm hydrograph in a particular year. In those years with many storms, we found that storms remove a lot of leaf material from the stream bed; it's not all exported downstream, but a lot is deposited laterally onto the stream banks, not downstream. Those are years when we see some of the lowest levels of secondary production.

We can show through studies that you can have many anthropogenic disturbances such as clearcutting, fire, agriculture, and mining that disrupt detrital inputs to streams. Assessing the significance for the stream community is difficult in the face of multiple effects that confound the analysis; e.g., with clear-cutting, you can get altered hydrology, altered thermal regimes, enhanced sediment, nutrient and solar inputs, and shifts in the relative importance of detrital inputs and within-stream primary production.

These studies show that litter exclusion alone, without considering the multitude of potential direct and indirect effects, has a profound effect on aquatic productivity. Litter inputs alone influence abundance, biomass, and production of invertebrates. This emphasizes the direct importance of the terrestrial-aquatic ecotones. Therefore, maintaining or reestablishing riparian inputs are an important aspect to consider in the conservation and restoration of streams.

Here's a myth we need to discuss - "Invertebrates and microbiota in these headwater streams represent a minute fraction of living plant and animal biomass (true); therefore, they are not important in the export of organic matter to downstream areas (myth)". We tested this at Coweeta through the application of pesticides to a headwater stream. We found we had to treat seasonally (every 3 months) because there's a lot of recolonization. This slide shows shredder production vs. insecticide treatment (Figure 8). The pre-treatment production of shredder biomass was 3.5 g/m^2 for the year. Following the first year of insecticide treatment, this dropped to 0.4 g/m^2. Most of the Plectopterans and caddisflies were eliminated. Tipulids are very resistant (you have to kill them with rocks); even with litter exclusion they were the last shredders to leave. They switch over and start eating the wood.

This is a slide of a leaf (Figure 9) that had been fed on by a shredding insect, a peltoperlid stonefly. One of the ways you can follow leaf decomposition in streams is to put known amounts of leaf material in a bag -- coarse-meshed, that allows animals to colonize the leaves. Then you can follow the rate of loss of that leaf litter in the stream through time. We did that in the stream that we treated with insecticide. (We also looked at microbial respiration rate on leaves in insecticide-treated and untreated streams. There was absolutely no difference in microbial respiration; therefore, differences in decomposition of leaves were due strictly to the animal community.) Our results

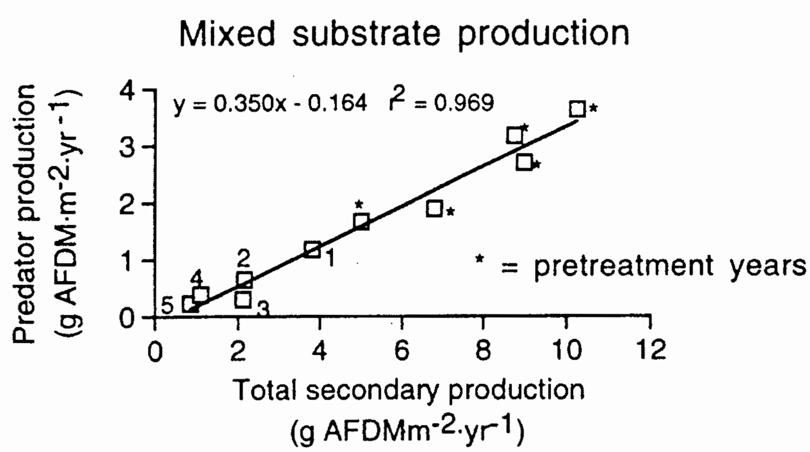


FIGURE 7

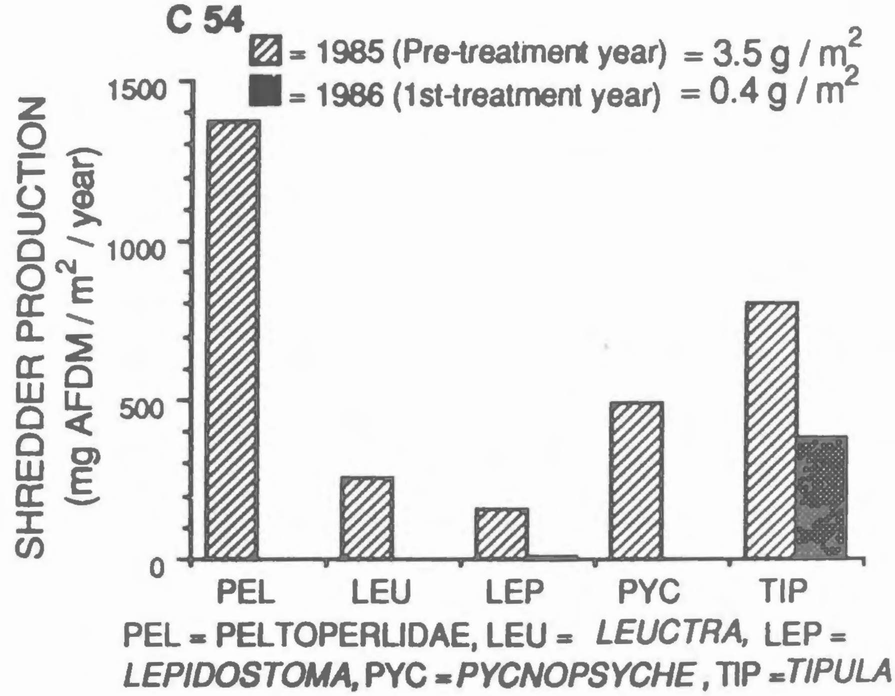


FIGURE 8.

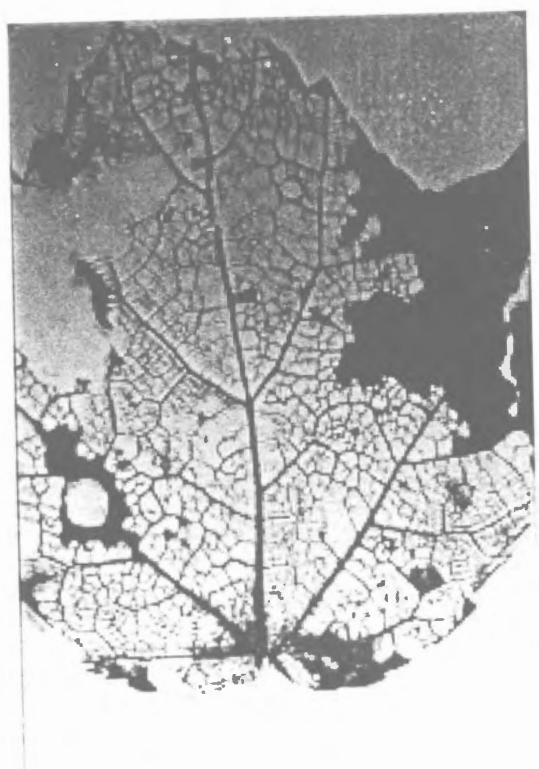


FIGURE 9.

are based on 11 years of data for untreated streams, with 95 to 100 litter bags per year, so this is a pretty extensive study. The average breakdown time for red maple leaves where invertebrates were present (untreated) was 275 days (Figure 10). On the other hand, if you treat and remove most of the invertebrate shredders (with the exception of Tipulids!), you end up with about 575 days. In other words, it takes much longer to break that material down when you remove the invertebrates.

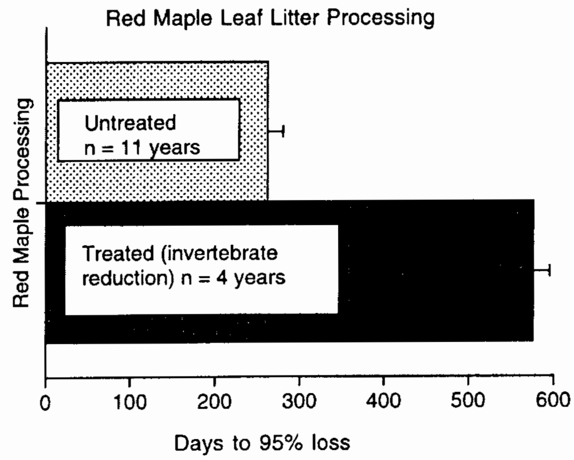


FIGURE 10.

These data show the same for rhododendron (Figure 11). Rhododendron is a thick, leathery leaf, very resistant to decomposition. It takes about 750 days to break down with invertebrates. With removal of large shredding invertebrates, it takes almost 1,800 days. The point is that the invertebrates are very important in the breakdown of some of this material.

Another thing to keep in mind is that invertebrates tend to have very low assimilation efficiencies -- about 90% of everything that enters the anterior end of the body (through the mouth) comes out the rear end as fine particles. In other words, they will assimilate about 10% of material intake and 90% is egested as fine particles. So they are actually grinding up this material into small particles which are more amenable for downstream transport. This slide on seston (organic matter suspended in the water column) concentration shows the effect of insecticide treatment (removal of most of the invertebrates) (Figure 12). During a three-year treatment with insecticides, seston was very low. It increased again after treatment ended, but it took about one year to recover.

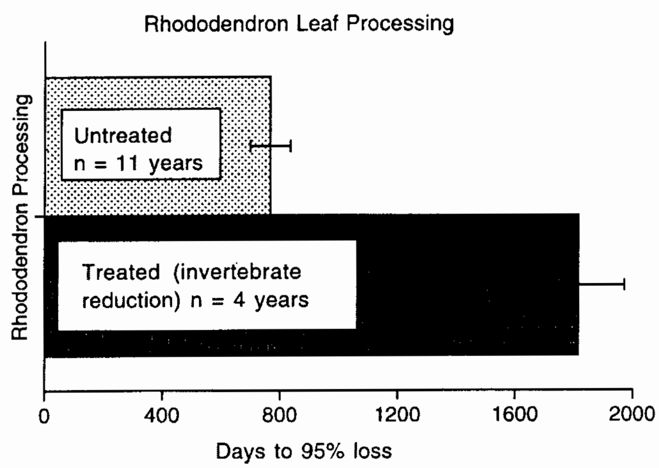
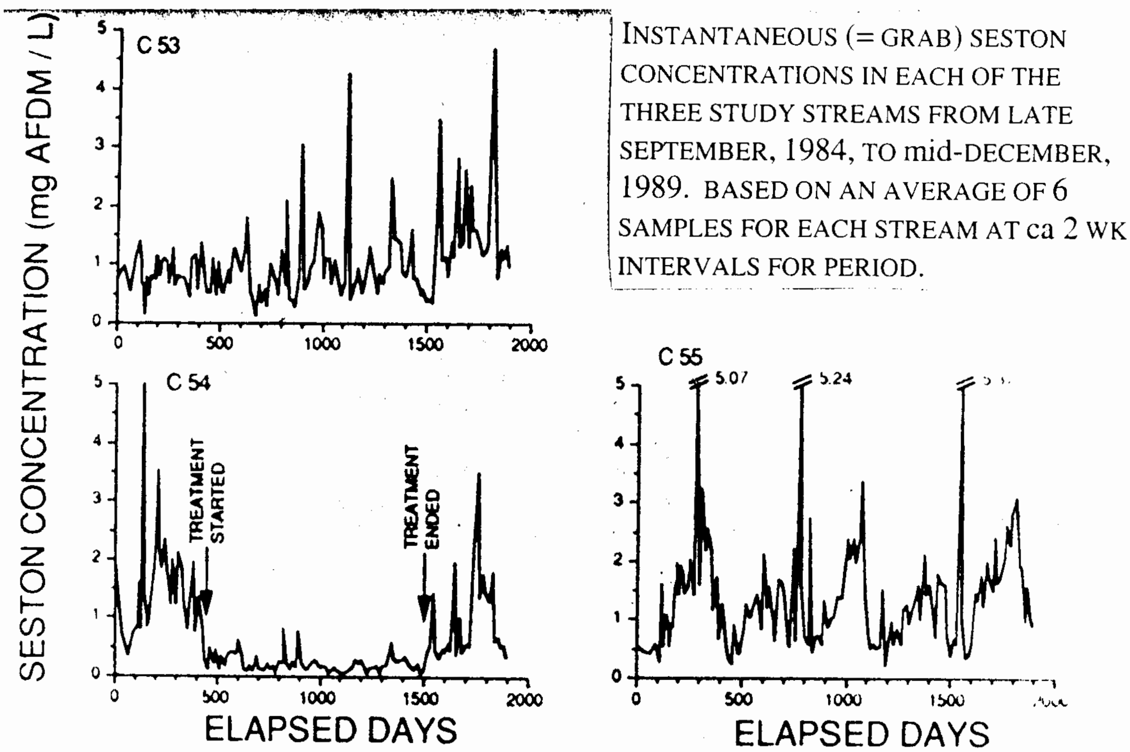


FIGURE 11.

Problem: We know a large amount of export occurs with individual storms. If you do continuous export as opposed to grab samples of export, you will find that continuous export is usually 30 to 40% higher, because with grab samples you're missing the little storm events (Figure 13) that transport much of the organic material. We also know there's a strong relationship between the amount of organic matter exported (coarse particulate organic matter or CPOM, or fine particulate organic matter, or FPOM), with maximum discharge during a given sampling interval. Export of material (Figure 14) is greater with high discharge.

Based on secondary production, the benthic macroinvertebrate production in the insecticide-treated stream was reduced by 1.2 kg/year for the entire stream. Also, the loss of invertebrate production over three years is 3.6 kg. We constructed models of FPOM export, incorporating discharge during each sampling interval, for each of the two reference streams and the treatment stream during the pretreatment year. Based on three-year treatment periods, we saw a reduction of 170-200 kg of FPOM export to downstream reaches in the insecticide-treated stream. With recovery of invertebrate populations (about 1.5 to 2 years), FPOM export approached pre-treatment levels.



INSTANTANEOUS (= GRAB) SESTON CONCENTRATIONS IN EACH OF THE THREE STUDY STREAMS FROM LATE SEPTEMBER, 1984, TO mid-DECEMBER, 1989. BASED ON AN AVERAGE OF 6 SAMPLES FOR EACH STREAM AT ca 2 WK INTERVALS FOR PERIOD.

FIGURE 12.

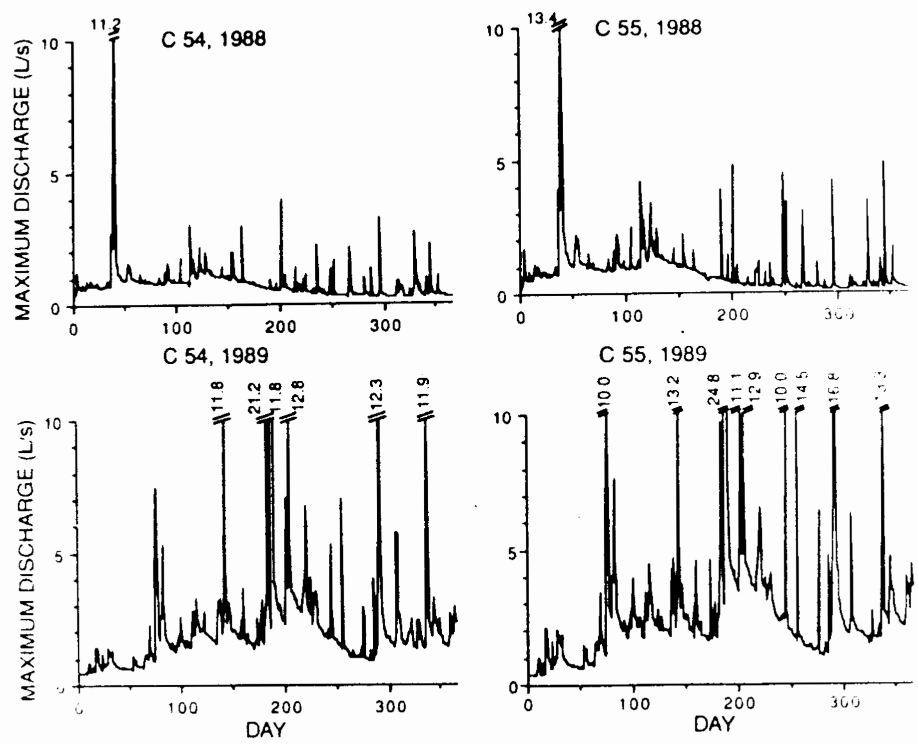


FIGURE 13.

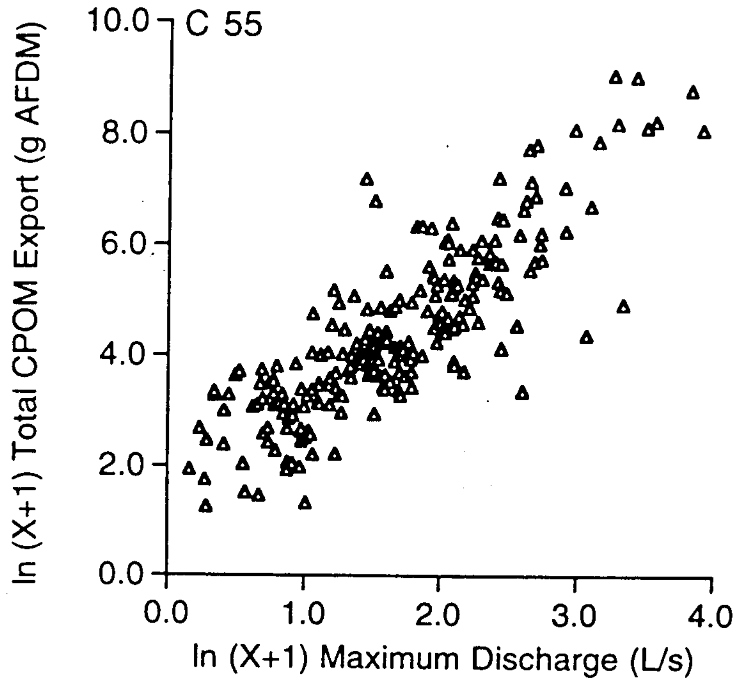


FIGURE 14.

I also want to emphasize that this is invertebrate reduction, and not complete extirpation, as animals recolonized between treatments or survived treatments. For example:

- Scrapers production reduced by ≈ 71%
- Shredders production reduced by ≈ 88%
- Gatherers production reduced by ≈ 21%
- Filterers production reduced by ≈ 98%
- Predators production reduced by ≈ 71%

So the roles for invertebrates in forested headwater streams are:

a) processing of CPOM to FPOM
b) increase downstream breakdown rates of leaf material
c) enhance downstream transport of organic matter as FPOM is more amenable to downstream transport than CPOM.

Leaves are not very amenable to downstream transport because of high retention of large particles.

Here is a quote from a consultant's report: "As a general rule, most small headwater streams have their organic import equal to their organic uptake, allowing the system to exist in a relatively steady state. The energy used just maintains the status of the existing benthics leaving little or no material for active transport (as averaged on an annual basis)." I'm not aware of any stream that works that way. In fact, it would not be a stream if it did.

Example: At Coweeta, Catchment 55, I want to point out that about 80% of the total input of that stream is CPOM from the surrounding forest. You can get about 10% as dissolved organic matter; you get a certain amount of through-fall as well as particulate inputs from the soil, which we have measured. There is very little primary production in these headwater streams as they are usually heavily shaded. The total annual input of organic matter is about 720 g/m^2 or so; keep in mind that 80% is CPOM input, and only 2 to 5% of the output is CPOM (Figure 15). Most of the material, about 56 - 62%, is exported as FPOM, and 30-40% as dissolved organic matter. So, these headwater streams are very important as sites of deposition, transformation, and subsequent export to downstream reaches.

If we look in terms of the total export (in terms of ash-free dry mass, kg/year; Figure 16) (Remember that these are extremely small streams , 0.035 cfs to 0 .061 cfs), the total export is 145 - 167 kg/year. Another way to look at this is annual export per m length of stream. We get about 1 kg of export per m length of stream. Looking at total lengths of first and second order streams found in the Coweeta basin, there are about 44.7 km. You can estimate values of the export of this organic matter to downstream reaches: 44 to 45 metric tons, or 50 U.S. tons, per year. And this estimate is low because of underestimation of stream length from maps.

I did a similar analysis for all the streams I could find in the eastern U.S. (Appalachian, ridge and valley, piedmont (White Clay); Figure 17). Note that none of the streams on the slide approach 5 cfs. As you see, by examining total annual organic matter export, with increasing discharge and increasing stream length, there's a general tendency toward more annual organic export per linear m as you go into larger streams. Not surprising -- discharge increases, stream width increases, and stream power increases, but certainly there is this tremendous increase as you go downstream. So headwater streams can be very important sites of organic matter deposition and subsequent export to downstream reaches.

Is this stuff important downstream? You bet. Example: For a fifth order reach of Coweeta Creek, amorphous detritus makes up the large portion of flow of food through different groups of aquatic invertebrates (Figure 18).

Some other concerns from the point of view of stream ecologist: We are seeing increased nitrogen deposition in eastern North America (Figure 19); it's a major problem in some of the forests. What's happening to nitrate concentrations in streams coming out of valley fills, where you no longer have some of these forest activities and microbial populations that might be playing a very important role in the nitrogen cycle?

Annual sources and input ($g\ m^{-2}\ yr^{-1}$) of organic matter to the stream draining Catchment 55 at Coweeta (prior to litter exclusion).

Allochthonous sources	**$g\ m^{-2}\ yr^{-1}$**	**% of total**
Direct fall[1]	492	68.6 %
Lateral movement[1]	137	19.1%
Dissolved organic matter ([DOM] soil water)	62*	8.6%
Throughfall (DOM) ≈	16*	2.2%
Particulate input from soil ≈	4*	0.5%
Total allochthonous =	**711**	**99.2%**
Autochthonous sources		
Primary production (algae) ≈	3.8	
Aquatic moss ≈	2	
Total autochthonous =	**5.8**	**0.8%**
Total annual input =	716.8	

[1] primarily leaves and woody debris

* inputs not curtailed by litter exclusion, in addition the efficiency of exclusion of the direct fall canopy and lateral movement fence was = 95%.

FIGURE 15.

How much organic matter is exported from forested headwater streams in the southern Appalachians? Data are based on 9-y of continuous measurements at the Coweeta Hydrologic Laboratory in western North Carolina.

	WS 53 Reference	WS 55 Reference
Watershed area ha (acres)	5.2 (12.9)	7.5 (18.6)
Stream length (m)	145	170
Avg. discharge L/s (CFS)	1.06 (0.035)	1.72 (0.061)
Annual range (L/s) [a]	0.33 to 1.56	0.52 to 2.48
Years of data	9	9
Export mg AFDM/L (total)	4.358	4.06
CPOM (% of total expt.)	0.106 (2.4%)	0.159 (5.2%)
FPOM (% of total expt.)	2.452 (56.3%)	1.904 (61.7%)
DOM[b] (% of total expt.)	1.800 (41.3%)	1.023 (33.9%)
Avg. export (g AFDM/d)	399.1	458.6
Export (kg AFDM/y)	145.7	167.4
Annual export (kg AFDM) per m length of stream	1.004	0.985
1st - 2nd order streams (m)[c]	44,700	44,700
Total estimated annual organic export (kg AFDM/y)	44,979	44,030
Export (metric tons/y)	~ 45	~ 44
Export (U.S. Tons/y)	~ 49.6	~ 48

[a] Includes record drought and wet years (65 years of record)
[b] DOM = assumes dissolved organic carbon (DOC) = 50% of DOM
[c] Includes a conservative measure of only total length of 1st and 2nd order streams in Ball Creek and Shope Fork Basins (1,483 ha or 3,673 acres) and does not include an additional 11 km of 3rd and 4th order streams.

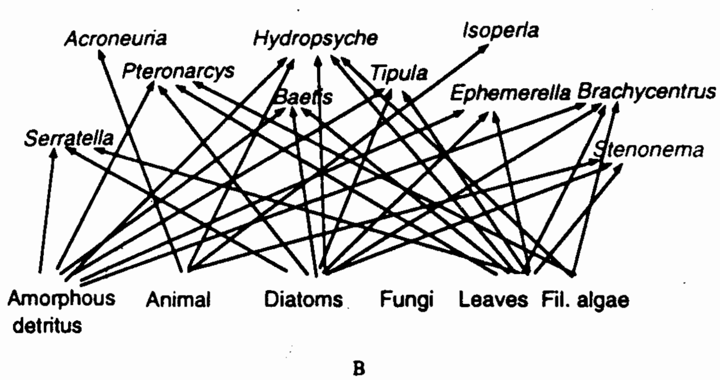
FIGURE 16.

What are some other measures of export per length of stream channel in eastern North American Streams?

Stream and Location	Physiographic Region	Avg. Annual Flow L/s (CFS)	Stream Order	Total Annual Organic Export (kg AFDM)	Annual Organic export (kg/linear m)
Catchment 53, NC	Appalachian	1.1 (0.04)	1st	399	1.0
Satellite Branch, NC [a]	Appalachian	1.7 (0.06)	1st	459	0.99
Walker Branch, TN [b]	Ridge & Valley	12 (0.43)	1st	2,010	5.9
Hugh White Creek, NC [c]	Appalachian	19 (0.67)	2nd	6,122	5.4
White Clay Creek, PA [d]	Piedmont	115 (4.06)	3rd	83,200	6.6

Sources: [a] Wallace et al. (1997); [b] Mulholland (1997); [c] Webster et al. (1997); and [d] Newbold et al. (1997) *in:* Webster, J. R., and J. L. Meyer (editors). 1997. Stream organic matter budgets: Journal of the North American Benthological Society 16:3-161.

FIGURE 17.



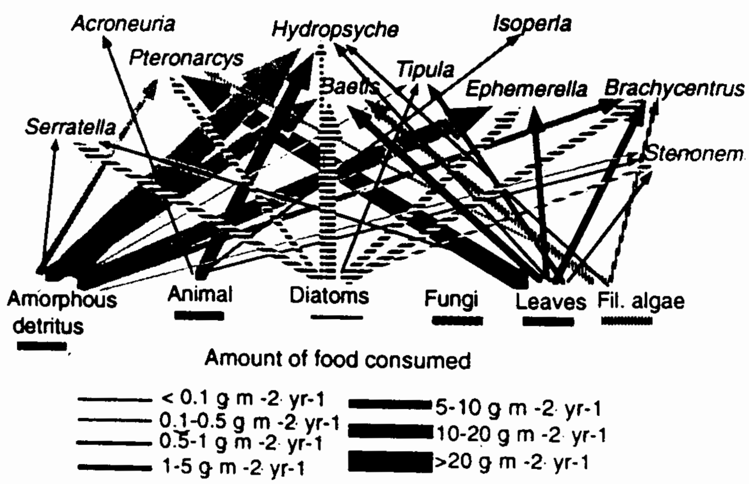
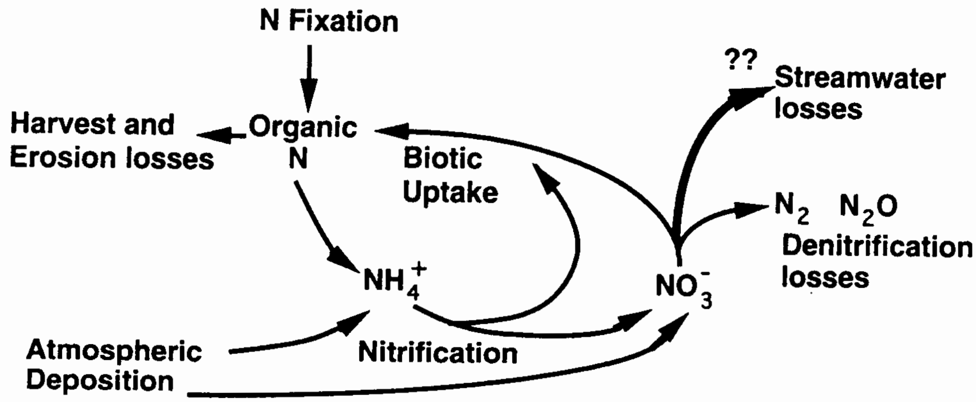


FIGURE 18.



- Primarily as a consequence of fossil fuel combustion, nitrogen deposition is increasing in much of eastern North America.
- Biotic uptake by vegetation, transformation by microbes in soils, riparian zones and streams, especially in the presence of available carbon are important mechanisms controlling the export of nitrogen from watersheds.
- How does mountain top removal and valley filling influence downstream nitrate concentrations?

FIGURE 19.

Another myth is that only flows greater than 5 cfs are streams. Only a lawyer would debate this question. How much is 5 cfs? - over 1 billion gallons of water per year. The average city in the U.S. uses 100 gal/day/per capita for personal use. In other words, if you looked at this in terms of how many people's water needs this could supply in a year, it's 32,300 people. Or, it would supply the personal and industrial needs of 16,000 people. If you could sell this water in Saudi Arabia, you'd be well off!

Another important point of concern: Stream thermal regimes can have important effects on microbial activity, invertebrate fauna, and fish. For example, for invertebrates these effects include eggs, larval growth, life histories, and seasonal cycles. What are the effects of valley fills and sediment ponds at the base of valley fills on downstream temperature regimes with respect to annual degree days, daily max-min (diel fluctuation), or seasonal temperature patterns? These things have a very important influence on the life cycles of aquatic insects.

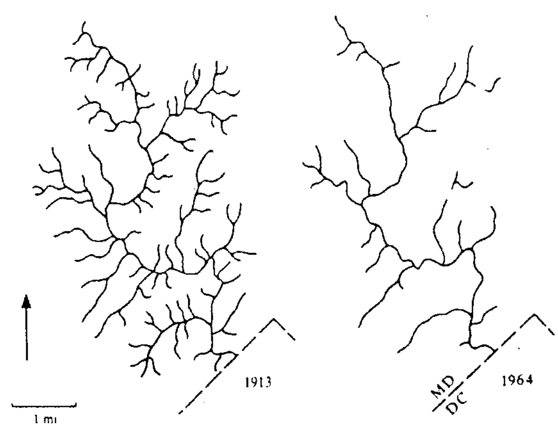
Another myth - There are so many kilometers of first order streams in Appalachia that destroying a small portion does not represent any potential threat to biodiversity. In fact if you look at papers by Morse, Stark and McCafferty - they make a point that the southern Appalachian region and the Appalachians in general are regions of outstanding biodiversity. Morse et al. (1997) consider 19 species of mayflies, seven species of dragonflies, 17 species of stoneflies, and 38 species of caddisflies to be vulnerable to extirpation at present in the southern Appalachians. They suspect the numbers may be considerably higher than these; why? Many of the rare species are known from only one or two locations in springbrooks or seepage areas. Furthermore, many small streams, seeps, and springbrooks have been poorly explored. To add to the problem, immature (aquatic) stages usually cannot be readily identified to species; adult (aerial-terrestrial) males are often required for accurate identification. There are few taxonomic specialists for various groups. Knowledge of their distribution, ecology, life history, and habitat requirements is sorely lacking.

As a closing thought to this biodiversity question, especially because of the potential importance of small springbrooks and spring seeps to southern Appalachian biodiversity, I would like to leave you with a question: Can we continue to destroy and entomb, forever, potential important habitats for life on this planet -- without requiring extensive pre-impact inventories by competent biologists? I think it's a very dangerous thing for life on this planet to do that, and to destroy streams where there is no complete biotic inventory.

I realize that valley fills by coal mining is not the only process that eliminates streams. This overhead shows the effect of urbanization on Rock Creek in Washington, D.C., 1913 to 1964, as you vary and extirpate first and second order streams (Figure 20). We need to be considering some of the hydrologic consequences downstream. It's not fair to equate these [valley fills] to what happens with urbanization, but with Rock Creek, the creek became muddy and silty, there was an increase in annual flood frequency (it's increased 10 to 20 times since about 1913), and downstream increase in channel width and depth associated with increased peak discharge.

PASSMORE - A LOT OF STREAMS DOWNSTREAM OF VALLEY FILLS HAVE RIPARIAN ZONES, SO LEAF LITTER IS PRESENT IN LOT OF CASES. BECAUSE OF THAT, HOW DO YOU ESTIMATE WHAT'S LOST FROM WHAT'S NO LONGER THERE, HOW IMPORTANT IS THAT FOR THE DOWNSTREAM REACHES, AND HOW DO YOU MEASURE IT? **WALLACE** - IT WOULD DEPEND ON THE SITE, AND YOU NEED TO MEASURE EACH ON ITS OWN. DOWNSTREAM OF WHERE WE'VE BEEN EXCLUDING LEAF LITTER AT COWEETA, WITHIN 100 M WE CAN FIND A FULL COMPLEMENT OF INVERTEBRATES AGAIN. **TIBBOTT** -- MAGGIE, WHAT YOU'RE SAYING IS, WE HAVE TO FIGURE OUT WHAT THE IMPACT IS ON THE DOWNSTREAM AREA FROM THE LOSS OF ALL THOSE TONS OF FINE PARTICULATE ORGANIC MATTER PRODUCTION IN THE BURIED REACH, RIGHT? **PASSMORE** -- WELL, I GUESS YOU'RE MOVING EVERYTHING DOWNSTREAM. **WALLACE** -- WELL, IF YOU MOVE EVERYTHING DOWNSTREAM, OVER THE LONG HAUL YOU GREATLY REDUCE THE AMOUNT OF EXPORT TO DOWNSTREAM REACHES IN TERMS OF PARTICULATE ORGANIC MATTER AND DOM, BUT I HAVE NO DATA ON DISSOLVED ORGANIC MATTER.

HANDEL - TO TIE IN WHAT YOU'VE TALKED ABOUT WITH THE PREVIOUS TALK ABOUT CURRENT PRACTICE AND HOW THESE LANDS ARE REVEGETATED: THE COMMON PRACTICE IS TO REPLACE MATURE HARDWOOD FORESTS WITH GRASSLANDS, WITH AN OCCASIONAL SMALL SEEDLING, AND THIS HAS ENORMOUS IMPACT ON PRIMARY PRODUCTION. AS WE LEARNED AT THE KENTUCKY MEETING SPONSORED BY OSM A FEW WEEKS AGO [THE TECHNICAL INTERACTIVE FORUM ON ENHANCEMENT OF REFORESTATION AT SURFACE COAL MINES, MARCH 23-24, 1999, IN FORT MITCHELL, KENTUCKY], THESE LANDS UNDER CURRENT PRACTICE RARELY DEVELOP INTO A FOREST -- THE PRODUCTIVITY RATE IS MUCH, MUCH LOWER BECAUSE OF COMPACTION, ETC. THE LINKS BETWEEN UPLAND PRACTICE AND STREAM BIOTA: SOIL REPLACEMENTS WHICH ARE PUT ON THESE MINES ARE TYPICALLY ENGINEERED FROM SUBSOILS, AND EVEN



Drainage basin of Rock Creek upstream of the District of Columbia in 1913 (left) before extensive urbanization and again in 1964 (right)(USGS, Dept. Interior 1964).

Note extirpation of many first and second order channels.

FIGURE 20.

THOUGH THEY HAVE SOME OF THE IONS THAT ARE APPROPRIATE, PARTICULARLY FOR GRASSLAND GROWTH, THEY LACK SOIL BIOTA WHICH ARE NECESSARY FOR PROCESSING AND FOR BIOTIC PRODUCTION THAT EVENTUALLY GETS DOWN INTO THE STREAM. SO I WOULD HOPE THAT THE APPROPRIATE AGENCIES PAY ATTENTION TO THE QUALITY OF SOIL ABOVE AND BEYOND PH AND CHEMICAL CHARACTERISTICS. YOU'VE CLEARLY SHOWN THAT WITHOUT PROCESSING OF THE ORGANIC PRIMARY PRODUCTIVITY, THE EVENTUAL BIODIVERSITY WILL BE AFFECTED. ALSO, THERE HAVE BEEN MANY ATTEMPTS IN RESTORATION OF COMMUNITIES NEAR STREAMS. IT'S BEEN SHOWN WITH SOME WONDERFUL STUDIES THAT THE KIND OF VEGETATION PUT NEAR STREAMS -- WETLAND SHRUBS AND HERBS -- REALLY AFFECTS THE KINDS OF ORGANISMS THAT LIVE IN THE STREAMS. EVEN THE SPECIES OF WILLOW THAT WILL GROW NEXT TO THE STREAM AND WHEN THEY LEAF OUT WHAT KIND OF INSECTS LIVE ON ITS NEW LEAVES AFFECTS THE FOOD WEB FURTHER ON. SO THERE'S A TREMENDOUS AMOUNT OF SUBTLETY ABOVE AND BEYOND JUST HOW MUCH PRIMARY PRODUCTIVITY IS THERE. ARE THERE ORGANISMS IN THE SOIL THAT CAN ILLUMINATE A TRUE BIODIVERSITY IN THIS REGIONAL AREA?

WALLACE (TO HANDEL) - ANOTHER POINT OF CONCERN -- DO YOU HAVE ANY FEEL, AS A TERRESTRIAL ECOLOGIST, FOR WHAT'S HAPPENING WITH NITROGEN? **HANDEL** - THE BEST STUDIES ARE IN WATERSHEDS THAT ARE HIGHLY DISRUPTED. I BELIEVE CLEARCUTS ARE MUCH MORE BENIGN THAN 5,000 ACRES OF SURFACE-MINED LAND, IN THE SENSE THAT SOIL STRUCTURE IN A CLEARCUT IS RELATIVELY UNIMPACTED COMPARED TO ENGINEERING A WHOLE BASIN. **WALLACE** - CLEARCUTTING IN COWEETA SAW INCREASES IN NITROGEN FOR A COUPLE OF YEARS, UNTIL REGROWTH, SO YOU HAVE NITROGEN UPTAKE WITH NEW GROWTH; BUT I HAVE NO IDEA WHAT'S HAPPENING WITH VALLEY FILLS; I HAVEN'T SEEN THE DATA. **HANDEL** - BASED ON INFORMATION IN THE FORT MITCHELL SYMPOSIUM, PRE-SMCRA PRACTICES MAY BE MORE EFFECTIVE FOR NATURAL REINVASION. BUT MOST OF THE NATURAL REINVASION WAS ON THE EDGES, WITHIN 100 YARDS OF THE EDGE - IT'S VERY UNCLEAR WHAT'S HAPPENING MORE TOWARDS THE CENTER OF VERY LARGE, ENGINEERED SITES.

HARTOS - HOW ACTIVE ARE BENTHIC CRITTERS IN EPHEMERAL OR INTERMITTENT PARTS OF STREAMS? **WALLACE** - I WOULD QUESTION, LOOKING AT SOME OF THESE THINGS THAT ARE CALLED "INTERMITTENT," LOOKING AT WHAT THEY'VE DONE WITH SOME OF THE PIGEONROOST SURVEYS. THE FAUNA THERE ARE VERY SIMILAR TO WHAT WE HAVE AT COWEETA. THESE AREN'T WHAT I'D CALL INTERMITTENT TAXA; THEY HAVE LIFE CYCLES IN SOME CASES THAT ARE UP TO 18 MONTHS OR LONGER, WHICH SUGGESTS THAT THERE'S WATER THERE FOR AT LEAST 18 MONTHS, OR THEY WOULDN'T BE THERE. **HARTOS** - SO THE LIMITING FACTOR ISN'T WATER, SO LONG AS THEY CAN BE INUNDATED AT CERTAIN PARTS OF THE YEAR? **WALLACE** - NO, THEY NEED CONTINUOUS WATER.

POMPONIO - YOU'VE DONE A GREAT JOB OF EXPLAINING THE PROCESSES, ETC. MY PROBLEM IS YOU DON'T GO FROM BUGS TO FISH. **WALLACE** - IT'S OBVIOUS! I CAN GO ON DOWN TO THE LITTLE TENNESSEE RIVER, DOWNSTREAM OF COWEETA, AND SHOW THAT 60% OF THE TOTAL INVERTEBRATE CONSUMPTION IS ATTRIBUTED TO AMORPHOUS DETRITUS (Q - WHAT'S AMORPHOUS DETRITUS? **WALLACE** - ORGANIC MATTER OF UNRECOGNIZABLE ORIGIN -- OFTEN HAS MICROBES ASSOCIATED WITH IT; MAY HAVE BEEN LEAF MATERIAL, ALGAL, WOOD, ETC.). A LARGE PORTION OF THE LITTLE TENNESSEE RIVER BUG PRODUCTION IS MADE UP OF AMORPHOUS DETRITUS. IT'S ONE OF THE MOST PRODUCTIVE LOCATIONS I'VE SEEN FOR A LARGE RIVER ANYWHERE IN THE WORLD. IT ALSO HAS 44 SPECIES OF FISH, A VERY PRODUCTIVE FISH COMMUNITY, INCLUDING A RIVER REDHORSE THAT'S THE LARGEST NEW SPECIES OF FISH DESCRIBED IN RECENT YEARS FROM NORTH AMERICA. **POMPONIO** - ....FEEDING OFF THE BUG COMMUNITY PRODUCED BY THE AMORPHOUS DETRITUS? **WALLACE** - YES. **POMPONIO** - THAT'S THE WHOLE THING!

KINKAID - IS IT YOUR SENSE THAT AS MATERIALS EVOLVE TOWARDS SOILS, ORGANIC MATERIALS WOULD BUILD UP? **WALLACE** - AS HANDEL JUST SAID, THERE'S VERY LITTLE ORGANIC MATTER. **KINCAID** - AS SOILS FORM AND WEATHER, THEY WILL BECOME INHABITED BY PLANTS AND MICROORGANISMS AND AS THESE MATERIALS BUILD, THEY'LL PROVIDE A SOURCE OF CARBON WHICH CAN INTERACT WITH RAINWATER PERCOLATING THROUGH. MY CONCERN IS THAT THE SAME MECHANISM THAT RESULTS IN THE FORMATION OF KARST TOPOGRAPHY WOULD BE ACTIVE OVER A PERIOD OF TIME, AND THIS IS A PROBLEM THAT NEEDS TO BE ADDRESSED IN TERMS OF STABILITY.

HANDEL - EARLIER, THE IDEA OF CREATING ENGINEERED STREAMS ON TERRACES WAS BROUGHT UP. WHAT MIGHT THE QUALITY OF STREAMS ON TERRACES BE VS. NATURAL? **WALLACE** - YOU COULD MAKE SOMETHING DIFFERENT; YOU COULD CONSTRUCT A WETLAND THAT WOULD BE DIFFERENT BUT CONSTRUCTING A STREAM, SOMETHING THAT RESEMBLED THE ORIGINAL -- I DON'T SEE IT. **HANDEL** - THE STRUCTURAL COMPLEXITY IS SO DIFFERENT ...

WALLACE - IT'S NOT GOING TO BE ANYTHING LIKE WHAT YOU STARTED OUT WITH; I'M NOT SURE IT'S FEASIBLE TO EXPECT SOMETHING THAT RESEMBLES THE ORIGINAL STREAM.

HANDEL - WOULD YOU CHARACTERIZE THE BIODIVERSITY OF AN ENGINEERED STREAM ON A MINING SITE COMPARED WITH A FORESTED NATURAL STREAM. **WALLACE** -- IT WOULD BE VERY DIFFERENT. IT MIGHT BE FAIRLY DIVERSE, BUT IT MIGHT BE EXOTIC SPECIES COMPARED TO WHAT WOULD NORMALLY BE THERE.

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Dr. Bern Sweeney, Stroud Water Research Center, Avondale, Pennsylvania

The Stroud Center has been studying the structure and function of stream ecosystems since 1967. During the first five years after opening its doors, the research team at the Center completed an intensive study of White Clay Creek, a small piedmont stream in a quasi-natural state. From those data, Robin Vannote, the Director and team leader at the time, formulated what has been referred to as the "River Continuum Hypothesis" -- a conceptual model viewing the stream ecosystem as a continuum from the first order headwater streams down through larger order rivers (Figures 1 and 2). One of the important things that impressed the team early on was the relationship between the stream and the terrestrial environment. This slide (Figure 3) shows leaf litter on a square meter of forest floor; the leaves were taken out of the square meter and weighed, and found to weigh 203 g. Leaf litter blows across the forest floor and into the streams. Because our streams are wet depressions in the landscape, you get a lot more organic matter in the stream than on the terrestrial floor. The leaves tend to accumulate behind things in the stream and don't go far in the stream; what does go far is the processed leaves. This slide (Figure 4) shows the standing stock of coarse particulate organic matter (CPOM) in a wooded area of our stream. Remember that the forest floor had around 200 g/m^2; in the stream in November we have a standing stock of about 800 to 1,000 g/m^2, about four times more in the stream channel than on forest floor, because as the leaves blow across the forest floor, they hit the stream, and they stay, and they accumulate in the stream channel.

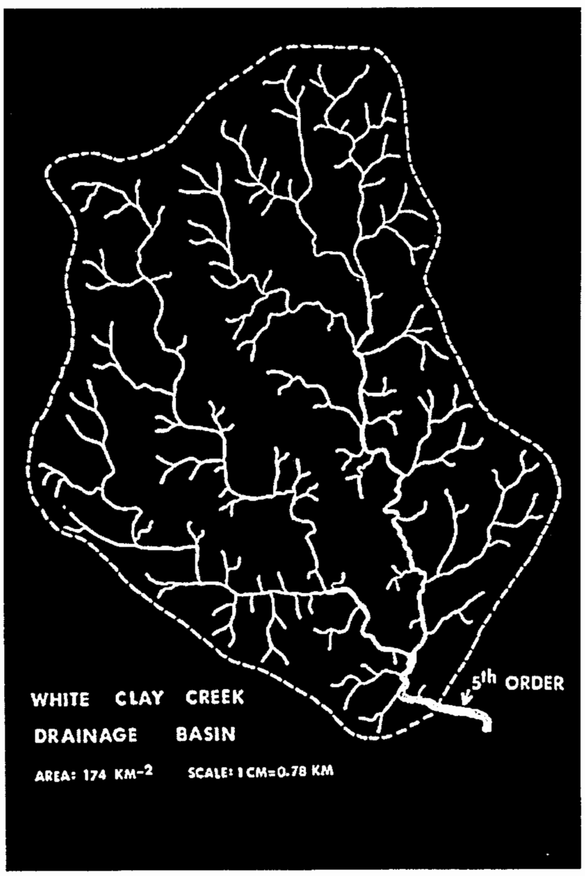


FIGURE 1.

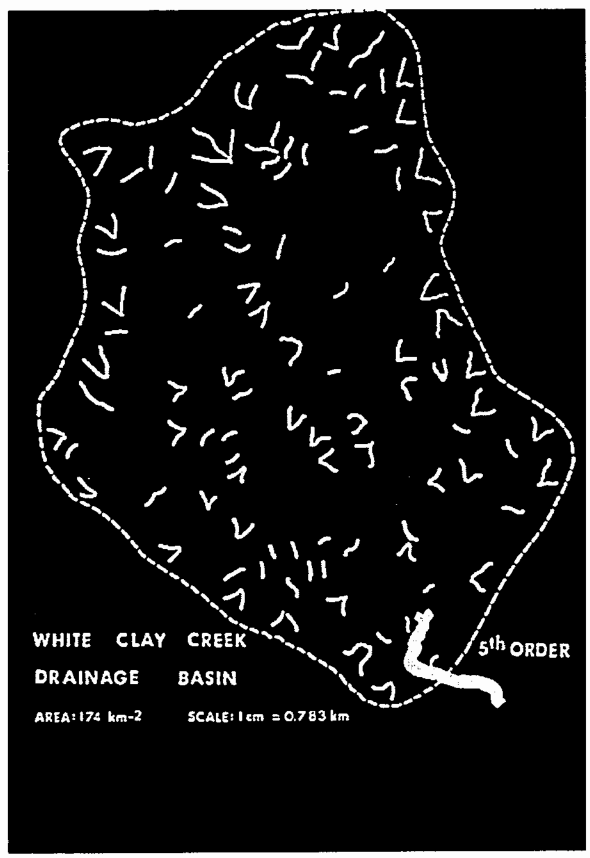


FIGURE 2. FIRST ORDER STREAMS ONLY.

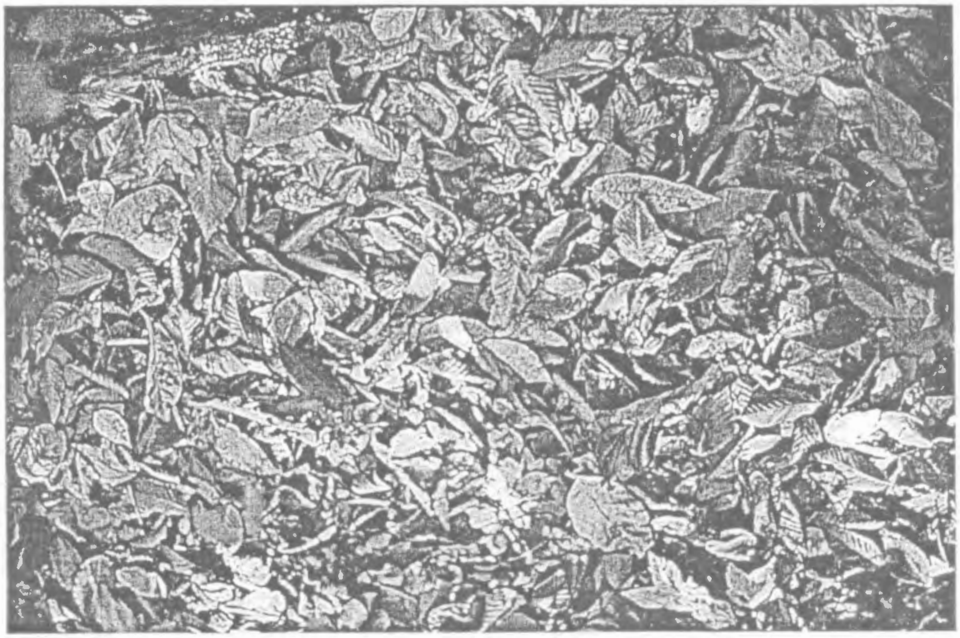


FIGURE 3.

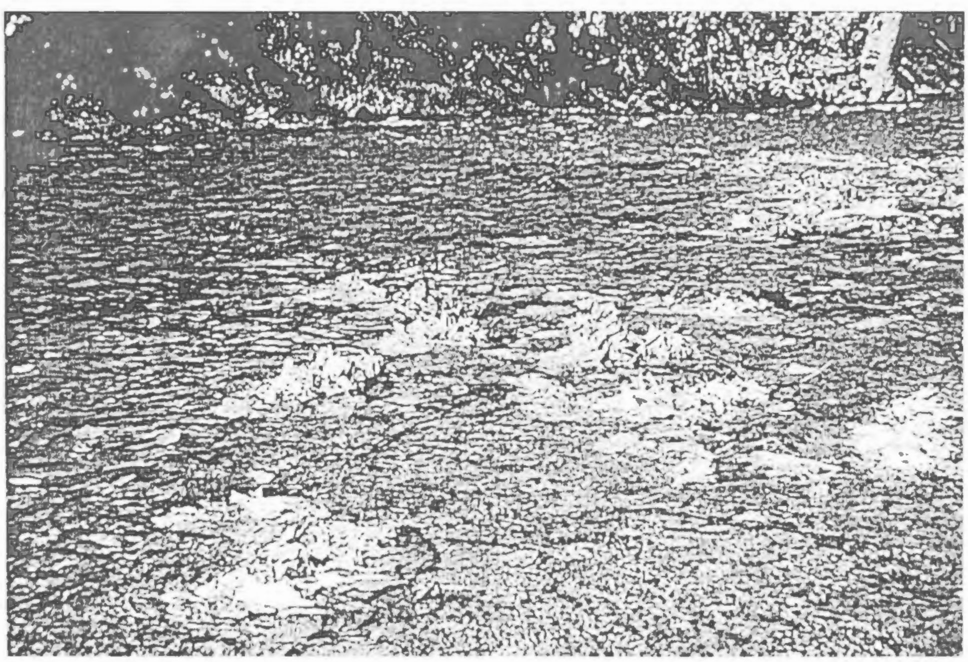


FIGURE 4.

Notice that this stream is flowing [from the forest towards a meadow (no animals in the meadow)] (Figure 5), and standing stock estimates were made in a downstream direction. The wooded section is very retentive; there is very little export of the coarse leaf litter down to the meadow. So you have two orders of magnitude lower leaf litter standing stock in the meadow. We just don't get the input of coarse organic matter in our grassy meadows that we do in our wooded areas. This is a concern regarding reconstructing streams in grassy reclamation areas.

HARTOS - HOW DOES LEAF LITTER CHANGE OVER TIME? **SWEENEY** - THIS TIME OF YEAR (APRIL/MAY) THERE'S VERY LITTLE OF THIS COARSE PARTICULATE ORGANIC MATTER IN THIS WOODED REACH OF STREAM. IT'S ALL BEEN PROCESSED. **HARTOS** - DOES IT SEEM TO WEIGH OUT WITH THE MEADOW BEING MORE CONSTANT? **SWEENEY** - I DON'T KNOW THAT. BASICALLY, THE PROCESSING OF THIS MATERIAL OCCURS IN THE FALL AND WINTER MONTHS BY INVERTEBRATES; BY THIS TIME YOU'RE LUCKY TO FIND A LEAF PACK, LET ALONE A SINGLE LEAF, IN THE STREAM.

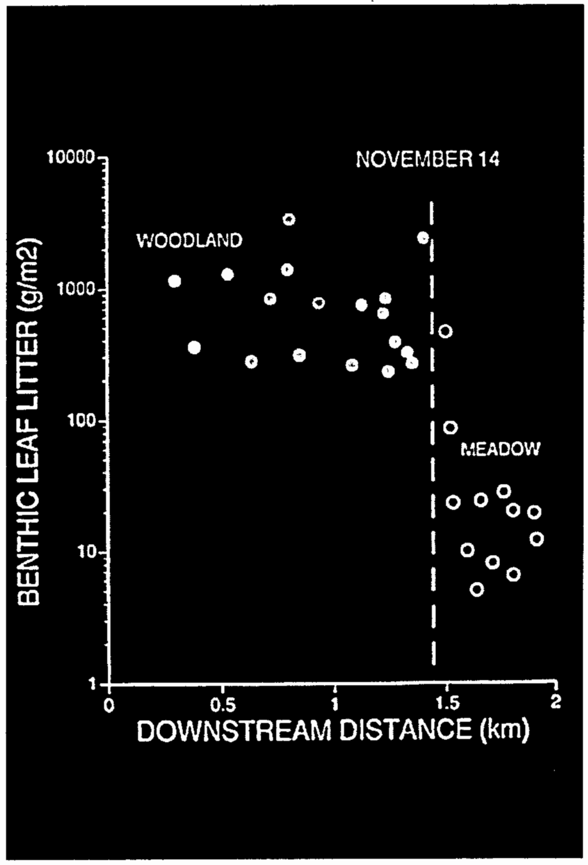


FIGURE 5.

This slide (Figure 6) shows leaf litter that's been processed by a lot of invertebrates. We measured production in our stream as Wallace did at Coweeta, and got the same kinds of values. We're getting about 5 g/m^2 (dry biomass) for this one species of stonefly on a mixed deciduous diet. We've also done exclusion experiments in our small, first order streams. We've shown that if you change the kind of tree species that go into the first order stream, you can dramatically affect the production and biomass of various invertebrates. For a particular stonefly, with a mixed deciduous leaf diet, we got about 5 g/m^2 of production, but when fed only on red oak leaves in a first order stream, we got only 1 - 2 g/m^2. So, the type of tree species growing next to these streams is really very critical to many of these invertebrates.

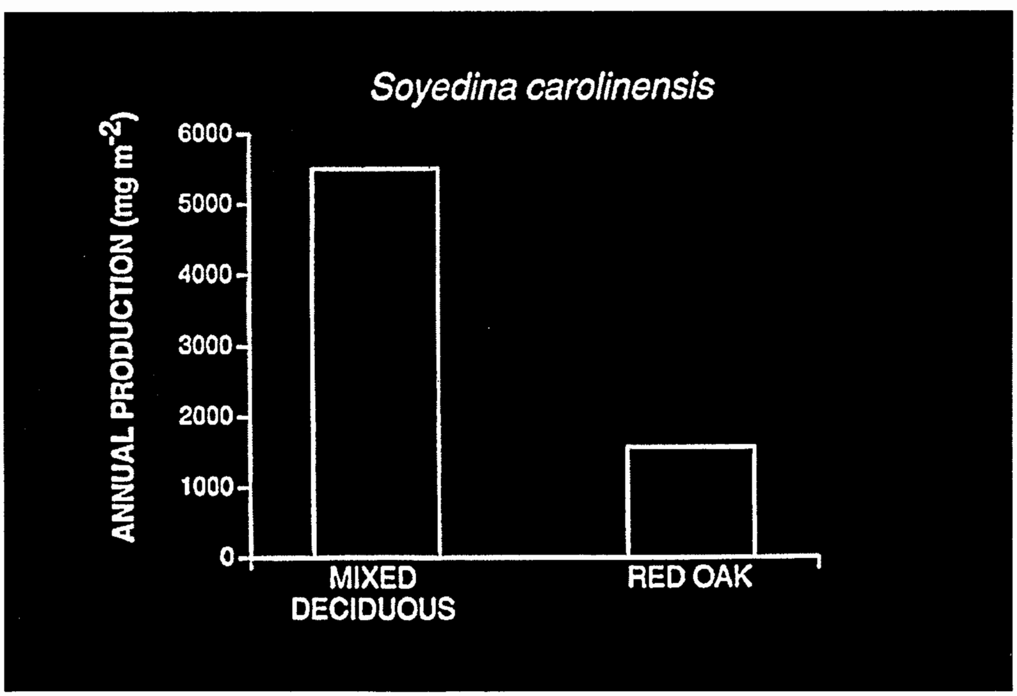


FIGURE 6.

The next slide (Figure 7) is an analysis of how much area there is in different order streams in our White Clay Creek basin. The slide shows how many streams of each type we have in the basin: 147 first, 47 second, 9 third, 2 fourth. It also shows the average width of the streams in a forested condition, and also the average lengths of tributaries in general in the United States. This is an attempt to try to calculate how much benthic area is available for production for biological and biochemical activities, because in streams a lot of the biological or biochemical action is taking place on the bottom substrates. This is very different than in a lake ecosystem or marine environment where there's a lot of water column processes. In a stream it's on the bottom -- benthos -- that's where the action is. So how much benthic area you have per unit length of stream makes a big difference per unit order of stream. You can see from this analysis that about 32% of total bottom area in our watershed available for macroinvertebrate production or any kind of production is in first order streams; this is a striking thing. First order streams are the heart and soul of a watershed. They're the place where the groundwater interfaces with the surface water. They're the collectors of materials on the landscape. First order streams are scattered all over the landscape. They're the first places where the terrestrial and the aquatic environment interface. (**Q**: HOW DID YOU MEASURE THE WIDTH? **SWEENEY** - THE WIDTHS SHOWN HERE ARE THE AVERAGE BASE-FLOW WETTED PERIMETER OF THE STREAMS.)

WHITE CLAY CREEK

ORDER	NUMBER	WIDTH (M)	LENGTH (M)	AREA (M^2)
1	147	3.0	1,609	704,838 (32.5%)
2	47	3.0	3,701	520,055
3	9	4.9	8,529	369,988
4	2	14.7	19,312	568,545
TOTAL				2,163,426

FIGURE 7.

In our experimental watershed, we have a lot of forest canopy which restricts light levels in the system, but in our first and second order streams we still get some significant primary production going on, because at certain times of year, especially this time of year, before leaf-out, when stream temperatures are high enough, we have enough light levels, we can get significant primary production. We can get up to 100-150 species of diatoms living on the surface of a rock in these smaller streams, tens of thousands of individuals, in this kind of area of stream bottom. Most of these algal species are diatoms because they can live at this time of year and under low light conditions in summer when the trees are shading the stream. This kind of algae is very important in these small-order streams because this was the dominant kind of algae, at least in our area, because it's a shade-loving kind of algae -- it competes well in shaded conditions -- and historically most streams were shaded in our region because it was part of the eastern deciduous forest biome. Consequently, most native species in our small streams that eat algae have mouth parts and digestive systems that are adapted to eating this type of algae (as opposed to filamentous green algae).

This slide (Figure 8) shows some old data (1972-1973) that are some of the first stream metabolism measurements ever made on a stream anywhere. The data are of dissolved oxygen measurements on small-order streams. You can see that in April and May, you have a time where you get a pulse of primary production. During shaded months, the streams are heterotrophic, but in late fall/early winter, when the canopy is gone and you have high sunlight, the temperatures

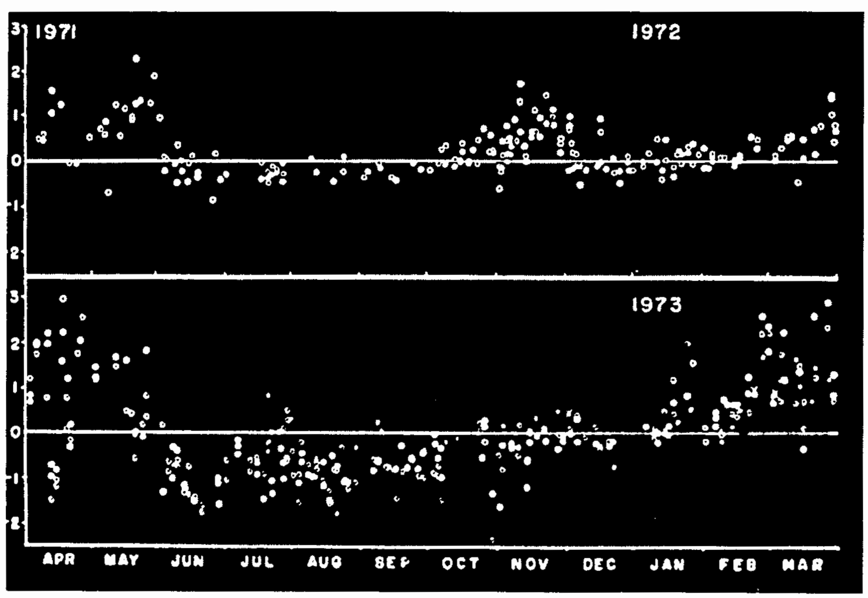


FIGURE 8.

are suitable and you get more primary production. Consequently, even in these small-order streams, besides the detritivores, you have a lot of herbivores. We have species that go through their life cycles that are timed very specifically to the availability of this primary production. So species like this will put on most of their biomass at a very narrow time of year and it has to coincide with that period of maximum primary production.

The next slide shows again that 203 g of leaf litter on the forest floor. One of the things that was recognized by our organic chemists after the first year or two of study on the White Clay was the importance that this leaf litter plays in the export of dissolved organic carbon to our low-order streams. When rainfall percolates through this leafy matrix on the forest floor, enters the ground as groundwater, and then flows to the stream, it picks up a lot of the organic compounds out of the leaves; at the Stroud Center, we call this "watershed tea." Just like the dark color you get when you steep a tea bag in hot water is the release of dissolved organic compounds that are food -- we drink it as food -- in a watershed, instead of having tea leaves you have hickory leaves, beech leaves etc., but it's the same thing. You have materials coming out of the leaf litter, and the leaves don't have to fall into the stream directly. These compounds go into the groundwater and are carried to the stream by the groundwater. We estimate in our system that this dissolved organic carbon fraction in our low-order streams represents a tremendous piece of the total food pie in the system (Figure 9). This is something which has to be looked at carefully in the mountaintop removal/valley fill situation.

This dissolved organic carbon drives a tremendous amount of productivity in the system. Our microbiologist tells us that in 1 square inch of stream bottom of the White Clay Creek, we have about 6.6 billion bacteria being fed by that dissolved organic carbon, 6 million flagellates (little microscopic animals), and 64,000 ciliates. Of course, this provides the basis for a good part of the food web that in turn gets exported up to larger invertebrates and fish.

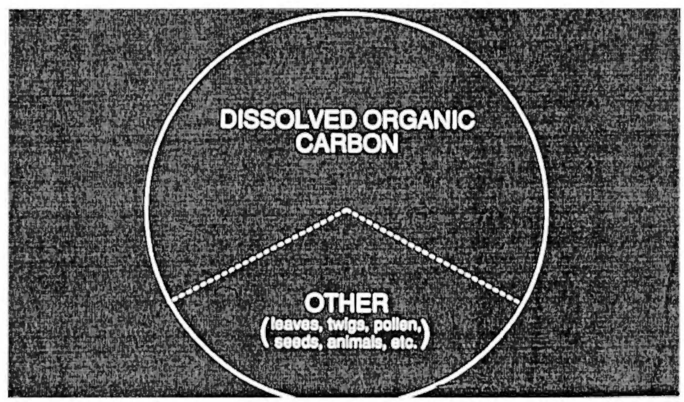


FIGURE 9.

The next slide (Figure 10) shows a schematic of a cross-section through a stream channel to show that streamside areas (wetland areas) along first and second order streams are extremely important not only for the dissolved organic carbon which comes through them, but also because they are zones of nutrient processing. Groundwater brings with it not only dissolved organic carbon, but also nitrogen and other types of nutrients. In our wetland areas, especially the wet soils in first and second order streams, we get a significant amount of denitrification going on. Shallow groundwater is moving through the streamside wetlands and into our streams.

The next slide (Figure 11) shows an analysis of nitrate levels in deep wells, surface springs, in the stream itself, and in shallow streamside wells. You can see that a lot of the nitrogen is being removed in shallow streamside wetland areas before it gets to the stream. This is another issue we've talked about this

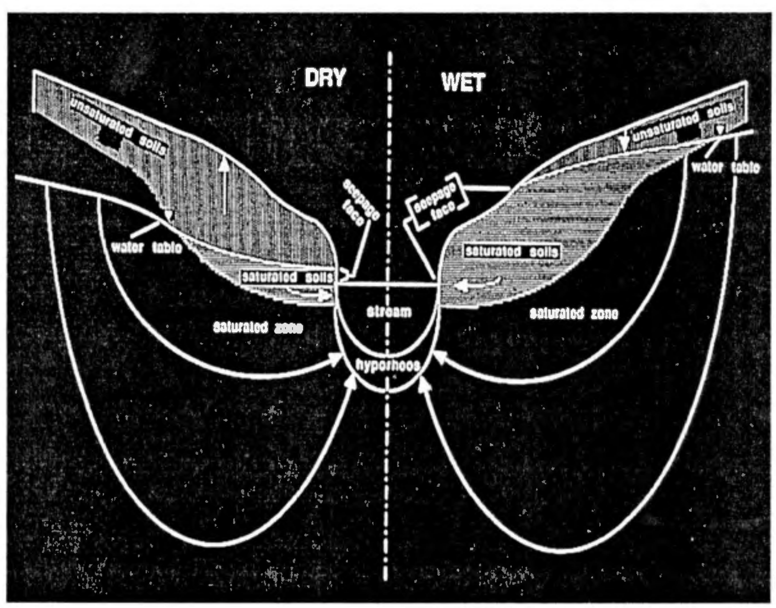


FIGURE 10.

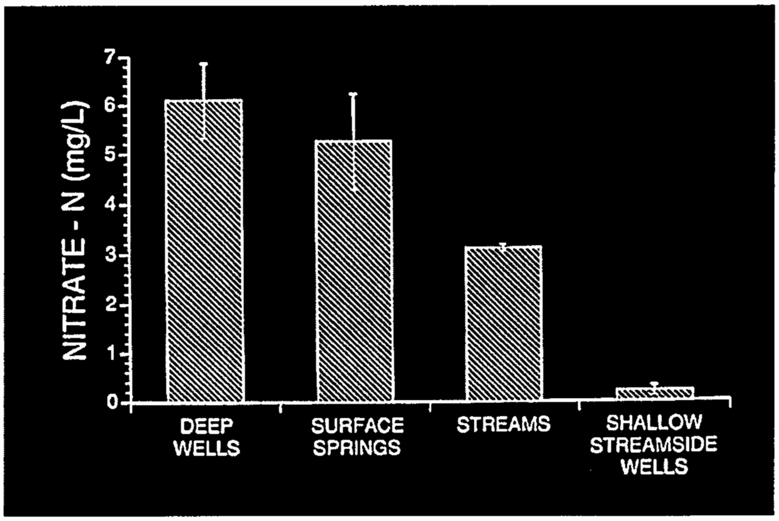


FIGURE 11.

morning: How different will these systems be without these kinds of processing areas for nutrients? We certainly have a lot of atmospheric nitrogen loading on our watersheds.

The next slide (Figure 12) is a schematic illustrating the connectivity between what's going on on the surface with water percolation and the dynamics of small streams. These small first order streams are really tightly connected to what's going on on the landscape through this internal plumbing network.

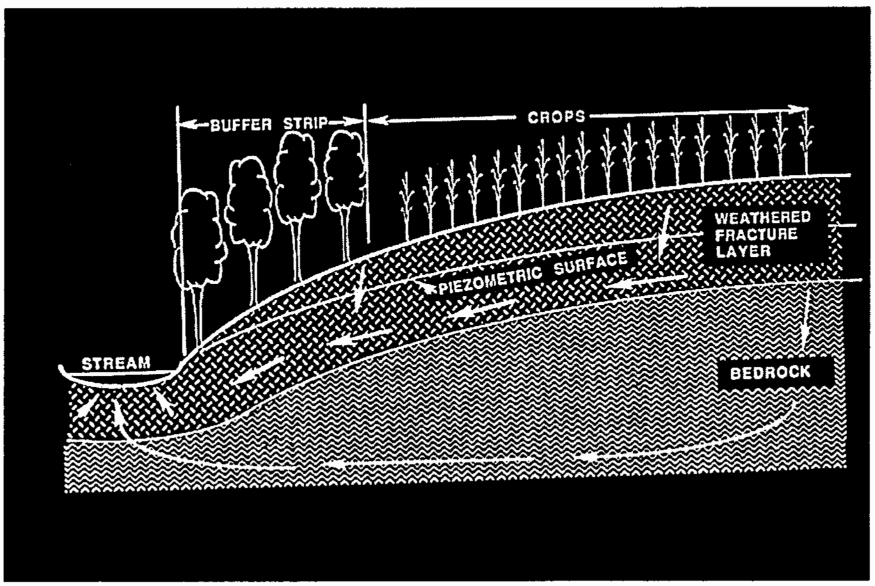


FIGURE 12.

The next point concerns the biota of these systems. The Center has been running Malaise nets which collect adult flying aquatic insects. It's the way that you inventory what species you have there. (You can't tell the species apart from the aquatic larvae for most taxa -- you need to get the adults.) We've been at this for 32 years, and have found up to 304 species in these small streams (Figure 13). We've done a poor job with dipterans, and I suspect that triple these numbers are really there, and the actual total species number will be over 600 when we're done. So we have a tremendous number of species brought in a very small linear length of stream channel.

The next slide (Figure 14) shows the Breitenback Creek in Germany. They've been working on this stream for about 50 years, and they're up to 881 species of macroinvertebrates. So high species diversity in these small streams is not uncharacteristic -- I think it's the norm.

SPECIES RICHNESS OF AQUATIC INSECTS

Insect Order	White Clay Creek* PA
Odonata (dragon/damselflies)	15
Ephemeroptera (mayflies)	50
Plecoptera (stoneflies)	14
Trichoptera (caddisflies)	52
Megaloptera/Neuroptera (hellgrammites, spongillaflies)	5
Hemiptera (water boatmen,striders)	10
Lepidoptera (aquatic moths)	3
Coleoptera (aquatic beetles)	18
Diptera (midges, craneflies, blackflies)	137
Total	304

* Stroud Water Research Center Survey

FIGURE 13.

BREITENBACH CREEK, GERMANY*

Macroinvertebrates	No. Species	% of Total
Insect	642	73%
Non-Insect*	239	27%
Total	881	100%

* Cited in Allan 1995; non-insect macroinvertebrates include Mollusca, Annelida, Crustacia, Hydracarina, Nematoda

FIGURE 14.

One thing we and others have discovered is that not only do you have high alpha diversity (that is, diversity at a given point in stream, so there's high diversity in first order streams, high diversity in sixth order streams, there's high diversity in the big river) but there's high beta diversity -- the turnover of species as you go down through this river continuum. It's extensive enough that there are very few species that you would find up in the headwaters of a system that also live downstream in the big river -- in fact, I can't even think of any. This is true for invertebrates and somewhat true for fish. My point is there's a continuum of species that have distinct distributions within the river continuum. In other words, a headwater species may only occur in first, second, and third order streams; you don't find it in fifth, sixth or seventh order streams. It doesn't have the right habitat, the right food, whatever. Also, there are species in a big river that you don't find in the headwaters. The point is - what happens when you clip off the top part of this continuum? What happens to a species that happens to only have a distribution in first, second, and third orders? You clip off first and second orders, and you have a much more affected population, restricted only to the third order. How long can that population persist? What happens if there's disturbance in middle of this continuum, say in a third or fourth order stream? What happens to the recolonization process? Are you going to get taxa from downstream going upstream? I don't think so, because organisms in the higher orders probably don't want to live in the lower orders. A lot of third, fourth and fifth order streams are where people like to live and develop the land -- this is where the housing developments are, this is where there's disturbance, and this is where accidents are going to happen -- this is where you'll need recolonization. Recolonization is going to come in from these smaller tributaries, if they exist. We need to think about these things in terms of the persistence of the system as a whole, not just as individual tributaries.

We haven't talked much about densities of invertebrates -- we've talked about production. In this system and others that we've studied, there's a tremendous density of macroinvertebrates and algae on the bottom of the streams. The density isn't really that size dependent. In these small first order streams, we get macroinvertebrate densities of 8,000 - 20,000 individuals per m^2. Down in our bigger watersheds, we get the same densities. So it's not the case that if you have a bigger stream you have more bugs per unit area. The kind of bugs are very different downstream (species are different), but the densities are pretty equal. So, a lot of people think of first order streams as a lot of "nothing" -- not much water in them, probably not much living in them. But in fact, the amount of organisms living per unit area is just as much as down in the bigger system. And the fact is that there is so much benthic area in these small streams, and there's so many of them, that collectively a lot of this "nothing" is worth something, and it's something very special -- it's very abundant.

This slide shows a first order stream bordered by grass. We've been studying paired reaches of these low order streams, reaches bordered by forest compared to reaches bordered by grass. In the grass section, the stream is not functionally as well off; the stream is only one-third as wide as the forested reach. A terrestrial forest will shade out grasses; if there is sunlight enough for grasses, they'll put roots in the stream which trap sediments, narrowing the stream bed in two to three years. Because organisms live on the stream bottom, and the productivity and biochemical processing is associated with the bottom area, narrowing will have a tremendous impact on stream productivity.

The last slides show the quality of the populations in a given stream and in broad sense. We have some genetic data published on mayflies in eastern North America. We're one of the few labs to study the genetic structure of aquatic insects. This slide (Figure 15) shows one of the species, which shows very different genes, moving from north to south. These data tell us that there's not a lot of gene flow occurring on a big scale. Gene flow in these insect populations occurs in a stepping stone fashion, as insects fly from one stream to another. What that means is that species like this which are occurring in first and second order streams need to have streams nearby for genetic exchange. So if there are gaps in the network, what are the implications for gene flow across the whole population? What we don't know may be very important. We don't even know what species are in these first order streams in the area [the mining region] we're talking about. The area of eastern West Virginia/western Virginia is a real hotspot of new species discoveries (Figure 16). It's unusual, non-glaciated, there's been a lot of time for populations to persist and evolve. Thermally, it has lot of diversity. We don't know what's in this area yet, and we don't know its importance to stream ecology.

We can't afford to destroy what we don't know. As a professional who has worked for 30 years in this field, should we be concerned about first and second order streams? We don't draw the line anywhere - we can't sacrifice a single first order stream (Figure 17).

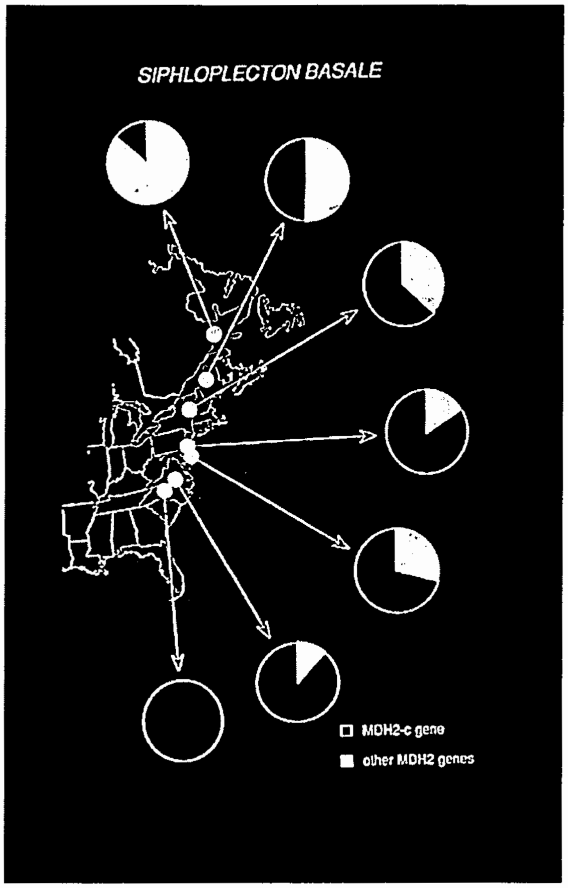


FIGURE 15.

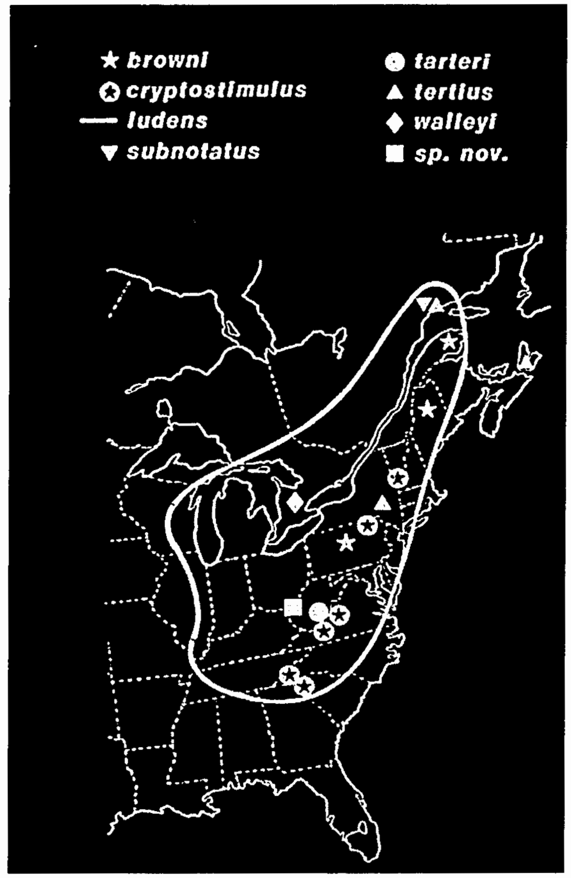


FIGURE 16.

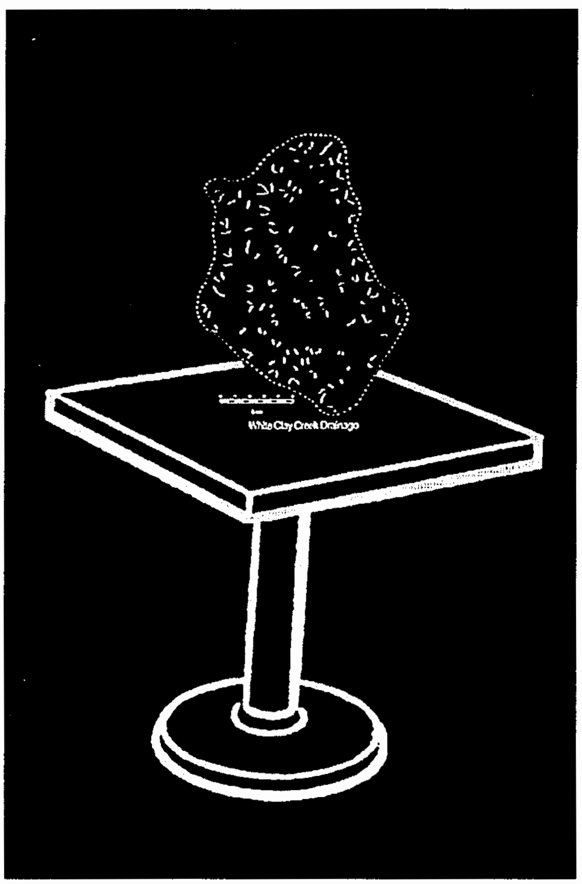


FIGURE 17.

KINCAID - GIVEN THE SHORT TIME FOR EIS STUDIES, AND THE CURRENT DROUGHT SITUATION, DO YOU HAVE ADVICE ON THINGS NOT TO DO? SWEENEY - GO ABOUT DATA COLLECTION VERY CAREFULLY. IF A STREAM IS DRY, DON'T ASSUME NO DATA CAN BE GATHERED. THERE ARE SOME GOOD PAPERS ON THIS REGION AND HOW TO SAMPLE QUANTITATIVELY. I THINK WE HAVE TO RELATE NUMBERS WITH PRODUCTION. YOU ALSO NEED SOME DATA FROM SOME OF THE ALREADY-DISTURBED SITES, SUCH AS THE TEMPERATURE REGIME FROM VALLEY FILLS AND HOW THEY ARE LIKE OR DIFFERENT FROM NATURAL STREAMS. TEMPERATURE DRIVES THE LIFE CYCLE OF MANY OF THESE SPECIES; MANY SPECIES HAVE EVOLVED SOPHISTICATED RESPONSES TO TEMPERATURE CHANGES. ALSO CHEMISTRY DATA ON WHAT IS BEING EXPORTED - NITROGEN, DISSOLVED ORGANIC CARBON.

Q: IF ONE WOULD RANDOMLY SAMPLE 20 STREAMS IN AN AREA, HOW DIVERSE DO YOU THINK THESE STREAMS WOULD BE ONE TO ANOTHER? SWEENEY - I'M NOT SURE WE KNOW. THE POTENTIAL IS TREMENDOUS. FOR EXAMPLE, BILL KAUFFMAN HAS DONE STUDIES WITH US IN COSTA RICA ON TWO LOW-ORDER STREAMS THAT ARE SEPARATED FROM EACH OTHER BY ONLY A KILOMETER. IN ONE, THERE WERE 200 SPECIES OF CHIRONOMIDS, IN THE OTHER THERE WERE 200 SPECIES OF CHIRONOMIDS, BUT THE DEGREE OF OVERLAP WAS LESS THAN

50 PERCENT. Q - SO THE UNIQUENESS THAT EACH OF THESE STREAMS REPRESENTS IS GOING TO HAVE TO BE ADDRESSED. **SWEENEY** - I THINK SO. THE PROBLEM, THAT I'VE TRIED TO CONVEY AND THAT BRUCE HAS TRIED TO CONVEY, IS THAT IT'S NOT EASY TO DO A TAXONOMIC INVENTORY OF THESE SYSTEMS. BUT JUST BECAUSE SOMETHING ISN'T EASY DOESN'T MEAN THAT IT SHOULDN'T BE DONE, OR THAT YOU SHOULD ALLOW SOMETHING ELSE TO HAPPEN BEFORE IT'S DONE.

POMPONIO - IS THERE ANYTHING IN YOUR STUDIES WHICH HAS LOOKED AT THE USE OF THOSE SYSTEMS BY TERRESTRIAL CRITTERS LIKE BIRDS? **SWEENEY** - YES, WE HAVE SOME DATA ON EXPORT OF AQUATIC LIFE. THE MALAISE TRAPS WOULD GIVE YOU DATA ON WHAT'S EXPORTED. ALSO WE KNOW THAT THERE'S A GREAT DEAL OF INTERACTION BETWEEN BIRDS AND INSECT POPULATIONS IN TERMS OF MAINTAINING SOME OF THE INTEGRITY OF THE LIFE HISTORIES, FOR EXAMPLE, EMERGENT SYNCHRONY. YOU HAVE A SPECIES THAT LIVES IN THE STREAM FOR A WHOLE YEAR, AND THEN ALL OF A SUDDEN IT EMERGES ON APRIL 10, AND ONLY APRIL 10-15 AND REPRODUCES. WHAT MAINTAINS THAT KIND OF SYNCHRONY? WE PUBLISHED INFORMATION SHOWING THAT TERRESTRIAL BIRDS FEEDING ON THE TAIL ENDS OF THE EMERGENCE PERIODS CAN MAINTAIN OR SELECT AGAINST INDIVIDUALS THAT EMERGE TOO EARLY OR TOO LATE. THERE'S A LOT OF THAT KIND OF THING THAT GOES ON. **POMPONIO** - I THINK IT'S IMPORTANT TO FOCUS NOT ONLY ON THE AQUATIC SPECIES, BUT ALSO WHAT'S USING THEM THAT'S AN IMPORTANT PART OF LANDSCAPE -- THE WHOLE INTERACTION. **SWEENEY** - WELL, I CAN TELL YOU THAT WHEN YOU GO OUT COLLECTING EMERGENT MAYFLIES AT CERTAIN TIMES OF THE YEAR, YOU'RE REALLY COMPETING WITH THE BIRDS.

[Note: Dr. Sweeney sent a letter to the Fish and Wildlife Service after the symposium, summarizing many of the points in his presentation. The letter is reproduced on the following pages.]

STROUD WATER RESEARCH CENTER

970 Spencer Road
Avondale, Pennsylvania 19311

Telephone 610-268-2153 610-268-0490 Facsimile

May 11, 1999

Mr. David Densmore
Supervisor
Pennsylvania Field Office
U. S. Fish and Wildlife Service
Suite 322, 315 South Allen Street
Sate College, PA 16801

Dear Mr. Densmore:

One of the key issues with respect to the Mountain Top Mining debate is whether small (first and second order) streams are important and worthy of unconditional protection and preservation? I offer the following thoughts in an attempt to convince you and others associated with the debate that the answer is an emphatic and unqualified YES!

The Stroud Water Research Center has been studying the structure and function of small tributaries of the White Clay Creek (WCC) Watershed since 1968. Results from the first few years of study quickly established the tiniest of streams (first order) as being both abundant and crucial to the overall function on the ecosystem. Vannote's "River Continuum Theory," which was first developed out of the early studies on the WCC, made special note of the importance of first order streams and their physical, chemical, and biological connectivity to the larger downstream tributaries.

Numerous studies over the years at the Center have shown that first order streams occur throughout the watershed, interface clearly with the landscape, and are the primary collectors of material and energy for the stream ecosystem. Under natural conditions, small streams receive leaf litter directly from the forest canopy and, because they are wet depressions in the landscape, often trap leaves blowing across the forest floor. Thus, small streams in WCC can have an average 800-1000 g/m^2 standing stock leaf litter in November even though the surrounding forest floor only averages about 200 g/m^2. These leaves are processed (eaten) by a variety of aquatic macroinvertebrate species and converted to animal biomass by some species at a rate of 5-8 g/m^2/year. Given that the WCC watershed contains about 147 first order streams which collectively contain about 700,000 m^2 of bottom area for macroinvertebrate production, the amount of animal biomass and smaller particles of food produced from leaf litter processing alone is staggering. Over 32% of the total benthic surface area in WCC is represented by first order streams. This is especially important because most of the structural and functional activity in a stream ecosystem is associated with benthic substrata (bottom areas) as opposed to water column processes.

Although small, natural streams in the WCC often flow through forest, seasonal openings in the canopy (Spring and Fall) and the occurrence of shade tolerant algae (diatoms) enable significant levels of primary production to occur. Studies at the Center have not only documented that each square meter of first order stream bottom is capable of producing significant levels of algae (~0.2 - 0.4 g C m^{-2} d^{-1}), but that individual rocks can often contain over 100 species of algae (diatoms) representing thousands of individuals.

Significant biological productivity in tiny first order streams of WCC is also associated with bacterial communities which are feeding on large amounts of dissolved organic compounds (DOC) carried to the stream by groundwater. The DOC, which effectively can represent up to 60% or more of the total food base of a small stream, originates from rainwater percolating through the organic matter (leaves, twigs, etc.) of the floor of the watershed. A square centimeter of stream bottom substrata in a small tributary of WCC can support a community consisting of about 1 billion bacteria being fed on by 1 million microflagellate and 10,000 ciliated invertebrates --- all supported to a large extent by DOC.

Thus, the in-stream biological productivity of first order streams is significant and certainly non-trivial compared to larger streams. In fact, widely accepted models of ecosystem structure and function (e.g. River Continuum, nutrient spiraling) strongly connect the productivity and structure of downstream communities with their smaller upstream tributaries.

In similar fashion, the chemical fingerprint of downstream reaches is determined in large part by the fingerprint of upstream tributaries. In WCC, for example, the wetland areas adjacent to first order streams are critical areas of denitrification for groundwater flowing into the system. Thus, despite high levels of nitrate in watershed groundwater (e.g. > 5-6 mg/l), nitrate levels in low order streams average < 3 mg/l.

The unique physical, chemical and biological conditions of low order streams supports not only a productive fauna and flora but a high level of diversity. In WCC, well over 300 species of aquatic insects alone co-exist in a small tributary. Both alpha and beta diversity are high in the system. Thus, species occurring in the small tributaries typically do not occur in the larger downstream reaches and vice versa. This means that eliminating first order streams greatly jeopardizes the ability of certain species to maintain local populations and provide propagules for recolonizing disturbed areas. In Appalachian mountain watersheds, the biological diversity of small order streams has not been studied extensively. Recent studies, however, indicate a substantial level of endemism and a disproportionately high level of species new to science associated with these small stream systems.

The abundance and proximity to one another of first order streams have also been shown to have important implications with respect to maintaining levels of genetic diversity in natural populations. For example, a comparison of the genetic structures of certain WCC populations with populations elsewhere (north or south) in their geographic range suggest that gene flow occurs in a "stepping stone" fashion (i.e. occasional short distance migration as opposed to long distance genetic exchange). Elimination of first order steams, or a portion of the "stepping stones", has obvious negative consequences for dispersal and gene flow of species uniquely adapted to these systems.

In conclusion, small first order streams form the heart and soul of the functional stream ecosystem in WCC and every watershed that has been carefully studied. They are small but numerous and collectively represent a significant part of the system with respect to its physical, chemical and biological characteristics. They support a wide variety of unique species that do not occur in larger streams. The structure and function of small streams is not only important locally (to the reach itself) but critical to the productivity of larger downstream tributaries. Clearly, any discussion of destroying even one first order stream is out of order. Rather, first order streams should be placed on a pedestal, protected at all cost, and treated with reverence in the sense of respect co-mingled with awe.

I hope that these comments are helpful to you and your staff.

Sincerely,

Bernard W. Sweeney
Director and Curator

Dr. Denis Newbold, Stroud Water Research Center, Avondale, Pennsylvania

This slide (Figure 1) shows the conceptual diagram of nutrient spiral in the stream. That concept was developed by Jack Webster of VPI, who published it with Bruce Wallace. The spiral tells you how effective the ecosystem is at processing nutrients. The tighter the spiral, the more effectively the ecosystem is trapping and reusing organic matter and nutrients as you go downstream stream. But there's another side of this: The tightness to the spiral which we measure with length (the distance something has to move downstream in order to be processed in some way) (Figure 2). This spiraling length (or "turnover length" when referring to carbon) has particular relevance to the question we face. If you're sitting in a downstream ecosystem, where did your nutrients come from -- how far upstream did they come from?

The original work on spriraling looked at the cycling of phosphorus. This slide (Figure 3) shows an upstream and a downstream caddisfly. In these original examinations of nutrient cycling, we could see evidence of spiraling taking place: a downstream caddisfly that collects particles in its net is actually getting labeled with radioactive phosphorus relative to the one upstream, providing the evidence that this downstream animal is depending on an upstream source.

I'm going to focus mostly on carbon, and shift to what we've learned in studies of White Clay Creek (but there have been a lot of studies at Coweeta and elsewhere showing similar things). A simple carbon cycle here (Figure 4) involves algae on the stream bottom, and/or microbes. As microbes decompose organic matter, or as algae produce organic matter through photosynthesis, they release a lot of dissolved organic carbon to the water column, which then moves downstream. Traditionally we viewed the organic matter in the stream, the dissolved organic matter especially, as refractory (i.e., it doesn't get used very fast; it eventually gets to the ocean where it may last a hundred years) (Figure 5). Much of the dissolved organic carbon (DOC) is, in fact, refractory, but there's also a significant labile component to that carbon which cycles within the stream ecosystem.

This slide (Figure 6) shows dissolved organic carbon cycling in White Clay Creek; it shows the fate of dissolved organic matter (in this case produced by algae, but it would be similar to that produced by microbes decomposing litter that falls into the stream). Based on our experimental results, the labile component of the DOC produced by the algae will travel 2 km downstream before being taken up and utilized by the streambed microbes. The refractory component will travel much farther. The estimate shown here of 144 km actually means that it would travel an average of 144 km downstream if the stream were not to grow any larger. But of course, the stream -- in this case, the White Clay Creek -- does grow larger, and in fact enters the Delaware Estuary in much less than 144 km. Thus, the 144 km actually means that nearly all of the refractory component will reach either the estuary or the ocean before being utilized. These estimates were based on the third order reach of the White Clay, and the 2-km turnover length for the labile DOC is about the same length as the reach. In fact, it turns out that the way these distances scale, the turnover length for labile DOC in a reach of any given order, will be comparable to the average length of a segment of that order (Figure 7). Thus in a first order reach, which is typically about 1 km long, the turnover length for labile DOC would be about 1 km. This means that we can normally expect about half of the labile DOC produced within any given reach to be utilized within the reach, while the remainder will be passed to a larger downstream reach. The next reach, which is typically second order with a length of 2 to 3 km, will have a proportionately longer turnover length, so the downstream transfer and utilization successively cascades downstream. Each downstream reach will utilize a portion of the labile DOC passed from upstream, and pass the remainder downstream.

The next slide (Figure 8) emphasizes the production of dissolved organic phosphorous, which has a lot of the same characteristics as dissolved organic matter.

Now I want to discuss the transport of fine particulate organic matter, or seston. We've been involved in a number of studies of how particles move downstream through a system. This is a diagram (Figure 9) of how particles might settle and be resuspended in the water column. We put radioactively-labeled particles in streams, along with red dyes to serve as tracers, and then sampled over several months after that in the sediments. From this work you get a picture of how much of these particles that are in the water column are settling, how long they stay on the bottom, and when they come back up, how far downstream they go. In a third order stream (Smiley Creek) in Idaho the

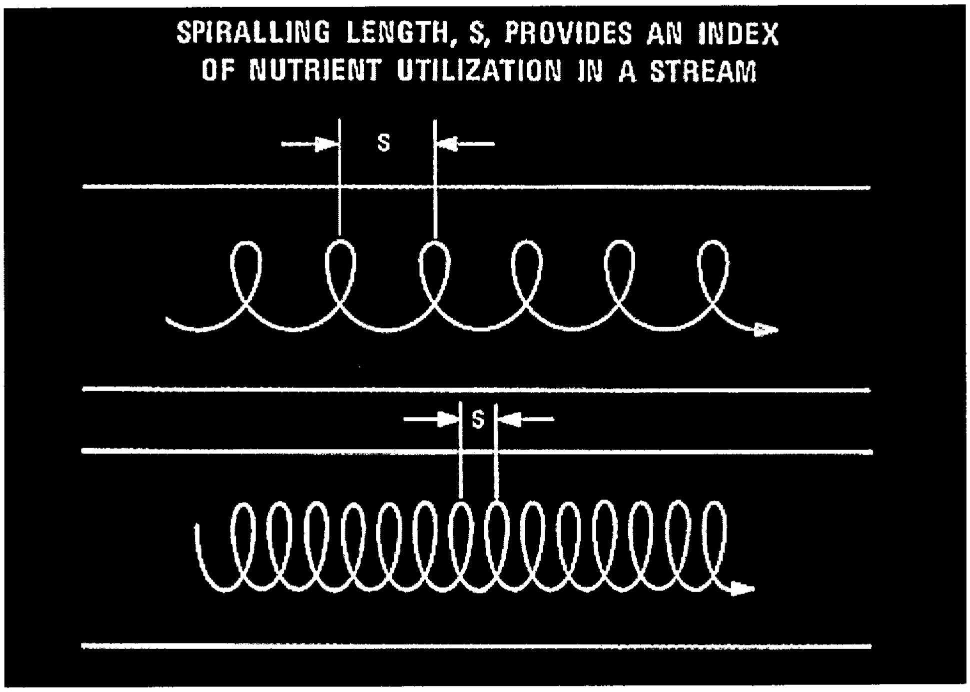
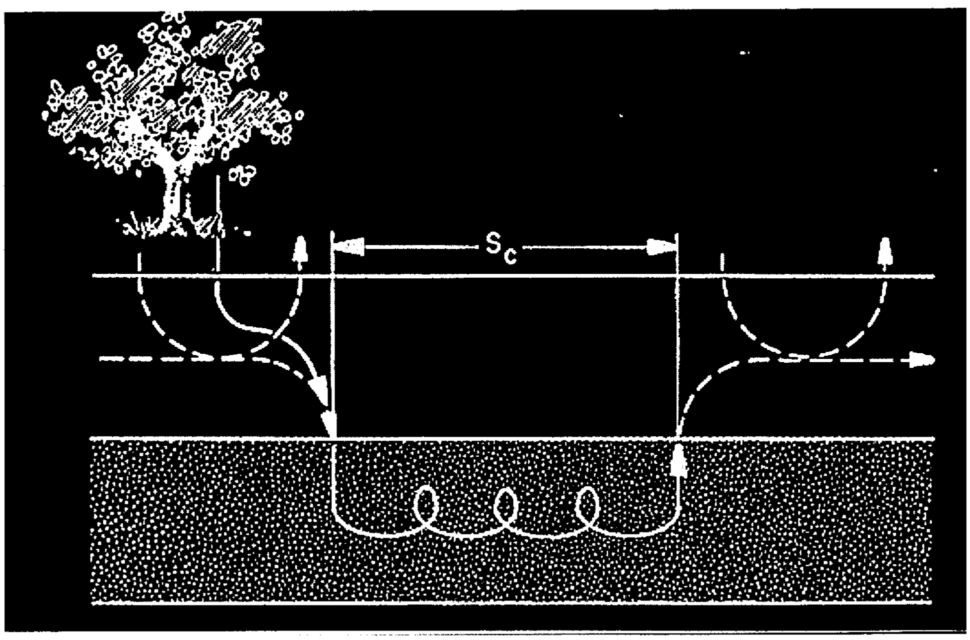


FIGURE 1.



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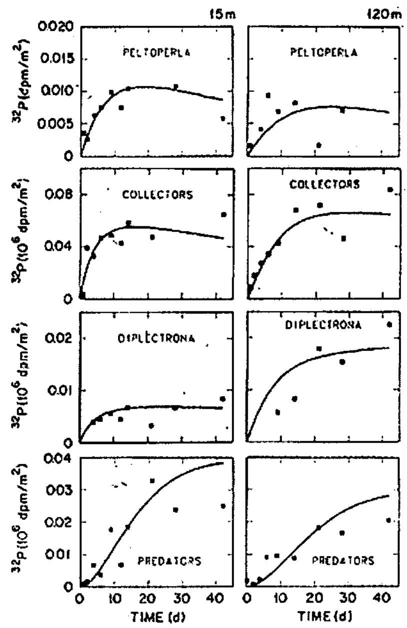


FIGURE 3.

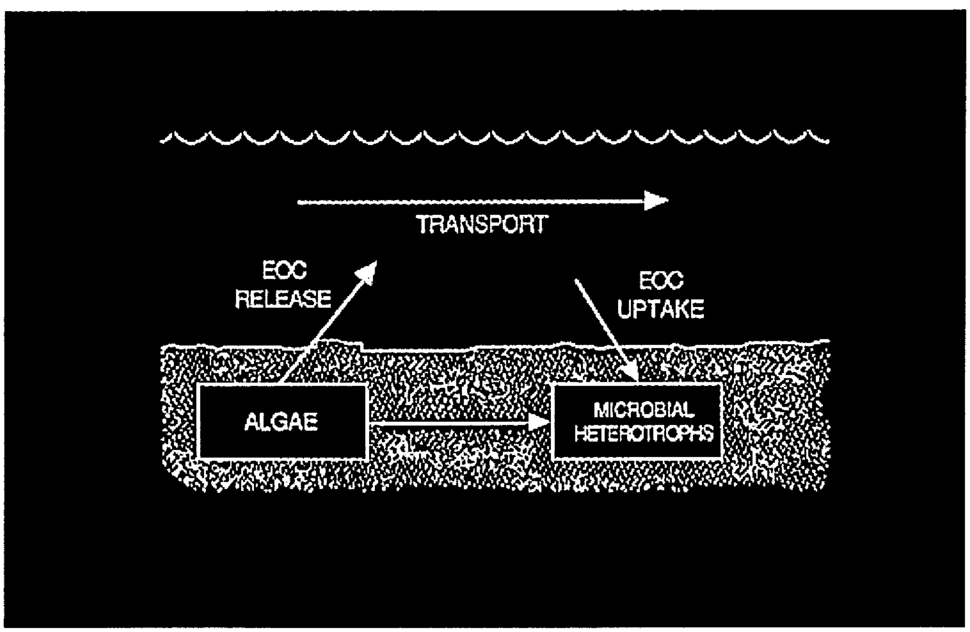


FIGURE 4.

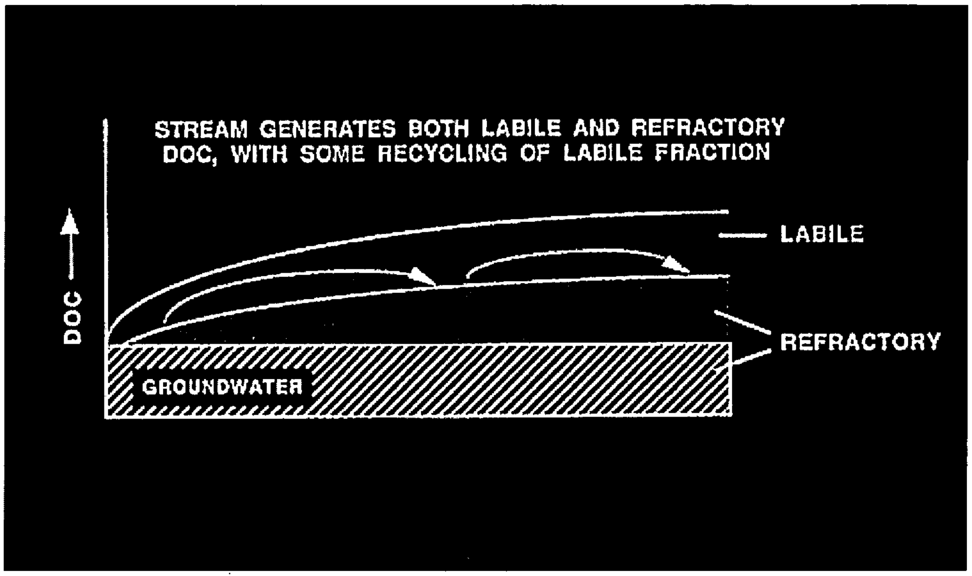


FIGURE 5.

DOC CYCLING IN WHITE CLAY CREEK

THIRD-ORDER REACH:
DEPTH, d = 0.2 m
VELOCITY, v_w = 0.12 m/sec
LENGTH, L ≈ 4 km

	LABILE	REFRACTORY
Mass transfer coefficient for uptake (from chambers) v_f	.04 h	0.0006 h
Turnover time, $T = d/v_f$	5 h	14 d
Turnover Length, $S = v_w T$	2 km	144 km
EOC Utilized within 3rd order reach	57%	1%
labile + refactory	35%	
Theoretical peak EOC Concentrations	0.4 mg/L	0.4 mg/L

FIGURE 6.

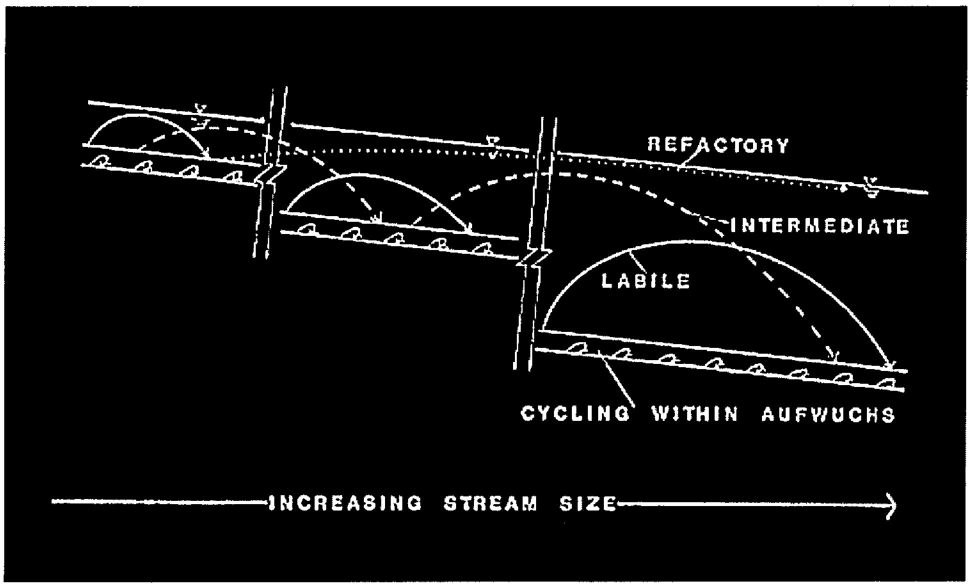


FIGURE 7.

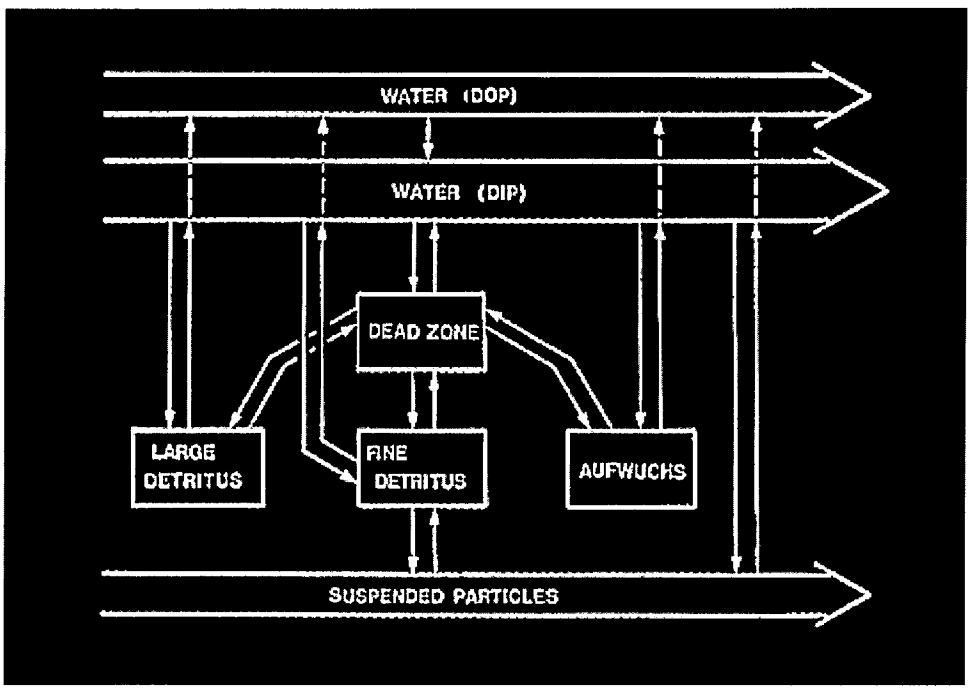


FIGURE 8.

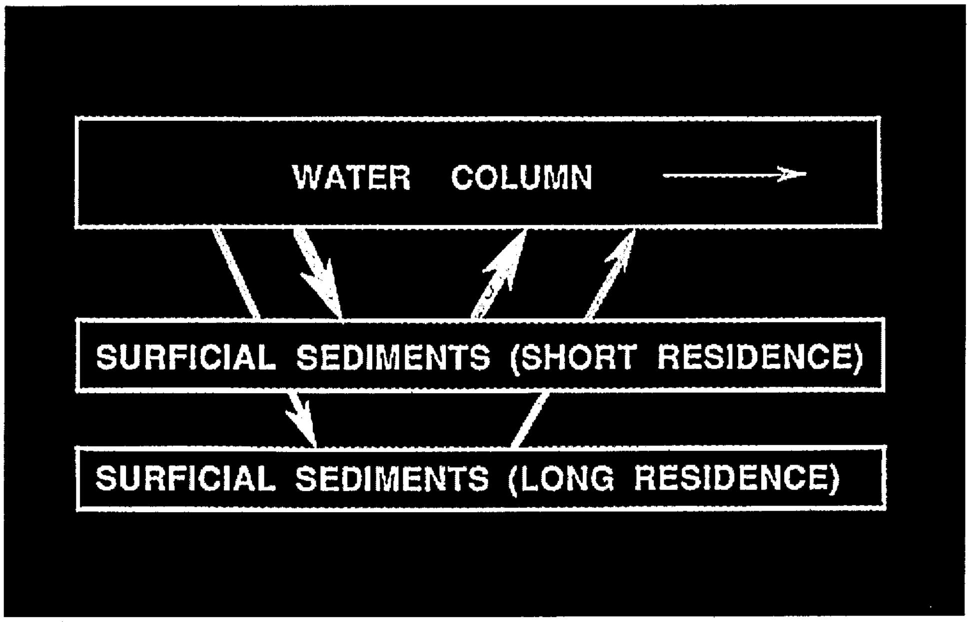


FIGURE 9.

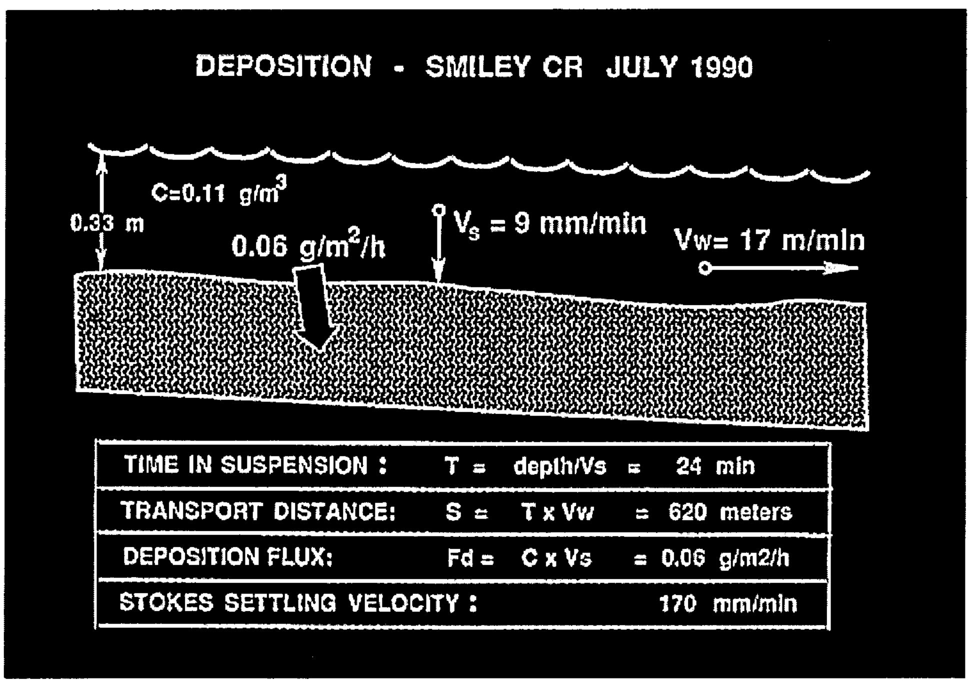


FIGURE 10.

transport distance for seston was 620 m (Figure 10). Again, this distance is on a scale with the length of stream we're talking about. By following these particles, we can say that a particle moves downstream 620 m, sits on the bottom for a period of 24 minutes (part of the fraction stays much longer), then it's resuspended and moves downstream another 620 m. So this material can move downstream great distances.

We know that downstream waters in estuaries are heavily dependent upon allochthonous carbon from upstream. This slide (Figure 11) shows a summary way of looking at turnover length concept. We can look at how long something lasts (wood lasts a long time, labile dissolved organic carbon may last only a few minutes, everything else is somewhere in between), vs. how fast it moves downstream; wood doesn't move very fast, both kinds of dissolved organic matter move downstream just as fast as the water moves. Different kinds of materials show tremendous ranges of turnover lengths. Drifting macroinvertebrates tend to stay put. Very fine particulate organic matter can move 10,000 km downstream, generally putting it into the ocean, refractory even farther, and on its way it feeds larger systems, rivers and estuaries.

[Overheads]:

1.

$$\text{Stream Ecosystem Efficiency} = \frac{\text{Inputs - Outputs}}{\text{Inputs}} = \frac{\text{Respiration}}{\text{Inputs}}$$

This reiterates some of the material Bruce was talking about. This is a basic way that we have of looking at processing in headwater systems: Stuart Fisher's concept of stream ecosystem efficiency.

2. The interesting thing is that while stream ecosystems tend to have a range of efficiencies, the basic median stream ecosystem efficiency is about 50% regardless of the size of the watershed. Stream ecosystem efficiency is not terribly dependent on size. We don't see a real trend, which is counter to what a lot of us thought earlier on... some thought that the bigger the stream, the more efficient.

3. As a general rule of thumb, about half of all the inputs to any stream get exported downstream, although it does have a range of 10 to 80 percent at the extremes. **Q** - AND IT CHANGES OVER THE YEAR, RIGHT? **NEWBOLD** - THIS IS AN IDEALIZED, LONG-TERM AVERAGE. THE NUMBER MAKES NO SENSE ON AN INSTANTANEOUS BASIS, BECAUSE YOU HAVE STORAGE, ETC. IT ONLY MAKES SENSE ON A 10-YEAR TIME SCALE. UNFORTUNATELY IT HASN'T BEEN MEASURED ON A 10-YEAR TIME SCALE; THESE ARE APPROXIMATIONS.

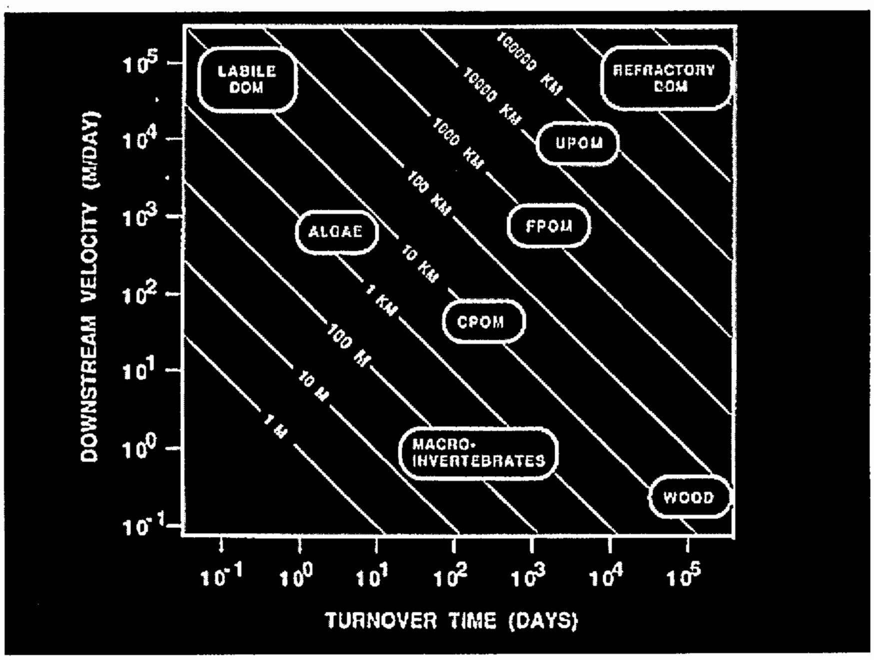


FIGURE 11.

4. This is something Bruce laid out, and I want to make a point on the issue of the inputs. We have litterfall, primary production (which now that we know how to measure it, can be more important in shaded streams than we had thought), and groundwater dissolved organic matter. Deep groundwater sources almost everywhere have low concentrations of dissolved organic matter, and that tends to be highly refractory because it's already been processed; it's been through the ground and there's not much left. But when you look at a stream, it has lots more kinds of dissolved organic matter, there's what's coming from the stream bed and the soil and riparian drainage that tends to be higher concentration and labile.

I don't know much about these fills, but when you think about a fill, you can think about rain coming onto the ground, picking up organic matter from grasses leaching down through, going through the standard process that happens to organic matter as it goes through the ground; it becomes this low-concentration refractory. Even though there's not a stream there, it will go through the ground, and eventually it will emerge below the fill, yielding low concentration refractory; it might be at about the same concentration it would have been without the fill. Yet the water emerging from the fill would be missing the labile dissolved and particulate organic matter, that would have been produced by the stream that is now buried, and it is this labile portion, produced within the stream itself, that supports downstream metabolism. We've calculated in the White Clay Creek that this labile fraction can account for about 20-30% of the metabolism of the stream in the reach.

5. Turnover length and stream organic matter budgets. As you get into larger and larger streams, the turnover length increases. In the smallest streams (10 liters per second down to 1 liter per second), turnover length tends to be about 1 kilometer. This material, even from these smallest streams, tends to move downstream about a kilometer, and feed the downstream reach. In terms of budgets, about half of it makes it that far down.

6. Turnover length of carbon is 1 kilometer or longer in first and second order streams. Turnover length increases with stream size. Organic matter cascades in increasingly larger systems.

7. Summary: A significant fraction of exported organic matter (OM) originates within the stream ecosystem and is labile. This is a combination of the point that says that the soil and the riparian areas next to the stream are a major source of organic carbon. And also, the decomposition of the litter and the primary production of material are also important sources of organic matter that get exported downstream. Most of the OM inputs to mid-order streams originated from first and second order streams. Based on these concepts, Bruce and Bern showed some data showing the frequency of first and second order streams. Between 60 and 80% of the water feeding a fourth-order stream came from first- and second-order streams. You can work this math out for any drainage basin. If you go all the way back to the geomorphology text of Leopold et al., and work out their miles of stream length against the stream sizes, each order has about the same bottom area and drains about the same drainage area as every other order. First, second, and third order streams are all roughly equivalent, to within an order of magnitude. So, if you're looking at fourth order basins, and you're potentially eliminating the first and second order streams, you find that they are contributing at least half of the water and drainage area and stream bed area to the downstream larger orders. Through this "50 percent rule" they are fully contributing their share, if not more, of the carbon in the system (it tends to be a little more because of the specialized habitat of the first-order systems). So we can calculate what this carbon influence is -- it's large --a large amount of the carbon is delivered downstream. We know that it's labile. There are some missing links -- such as exactly how that feeds back up into the food web in the downstream waters. But we can come to reasonable conclusions about the likely importance on all these points.

Dr. Jay Stauffer, The Pennsylvania State University, University Park, Pennsylvania

I'd like to talk about freshwater fishes and their role in headwater streams. Most of the time we're talking about brook trout, and *Cottus* (sculpins). We look at these as species that are common throughout their range, and in fact a lot of fish and game commissions will stock brook trout. In work that we did in the Potomac River in Maryland, we found brook trout in first and second order streams feeding the Potomac River (which had a pH of 4 or 5 on good days) that had been isolated populations for 150-200 years. We could distinguish these brook trout populations -- we could tell which stream a brook trout came from with about 98% probability. At the time I thought it was because they were isolated by the main channel Potomac River and its low pH. Now I think there are a lot of headwater streams that maintain discreet populations. There was discussion about reduction in genetic flow among aquatic insect populations. For fish, that reduction is even exacerbated because they do not have an aerial stage to their life histories -- they must migrate through water to get from one stream to another -- they can't fly over land barriers. So I think a lot of these populations are very much isolated. A former student of mine, Rich Raisley, who is now at Frostburg State University (University of Maryland) is describing many species of *Cottus* -- sculpins -- from many of the headwater streams in Pennsylvania, Maryland, Virginia, and West Virginia. At one time we thought all of these populations were conspecific, but it turns out they're not. So I'd like to talk about these fishes and ways of evaluating the potential for these stream systems to be harmed and then their potential to recover.

A lot of fishes that live in riffles are darters (*Etheostoma* or *Percina* spp.) -- they seem to be unique to particular stream systems. We've done a lot of instream, behavioral studies (many funded by the U.S. Fish and Wildlife Service) looking at the impact of introduced species on these darter communities -- where they breed, where they live, and what they eat.

The banded darter (*Etheostoma zonale*) was introduced into a headwater stream, Pine Creek in Pennsylvania, about 1950, and stayed there for a long time. It wasn't until Hurricane Agnes hit in the '70's that this fish was distributed throughout the Susquehanna River. When this happened, the other fishes (e.g., tesselated darter, *Etheostoma olmstedi*), hybridized with fishes all through the system. Many of you might be familiar with the Maryland darter (*Etheostoma salare*), which occurred in Deer Creek and Swan Creek in the Susquehanna River drainage, just over the Pennsylvania border. This species now, I'm confident, is extinct. We last had a siting of that fish about 10 years ago and we haven't found it since then. Its disappearance was coincident with the introduction of *E. zonale* into Deer Creek and Swan Creek by Hurricane Agnes. Once it got into that part of the Susquehanna, *E. salare,* the Maryland darter, disappeared.

These headwater streams are particularly important, because if you study evolution and are familiar with the work of Mayr and some other people, you find a founder effect, which is very important in the evolution of species. In many of these headwater streams we have isolated populations that are separated, or sometimes disjunct, sometimes with minimal gene flow with the main body of the population. So these fish are a little bit different anyway, they're on the edge of their range. So they're very much subject to natural selection, and different forces which probably drive speciation and evolution of these fishes. So these headwater areas contain what Mayr and others have called "semi-species," or "incipient species." There might be a population where some taxonomists would not give it species status at the time, but maybe 10 years from now, 100 years from now, or 1000 years from now the speciation process would take place. So these fishes are very important, because they're slightly genetically distinct, they're certainly phenotypically distinct -- they look different -- because they're under different selection pressures and environmental pressures that cause phenotypic plasticity.

So these fishes are a little bit different, and they need to be preserved. I think we need to look very carefully at what's in these headwater streams. One of the speakers this morning talked about it's a mistake to go in and alter these things before we know what's in them. We think fish fauna are well-known, and I'll talk about that more later. We have other fish species that have pockets in headwater streams -- they're just isolated in these headwater streams, and there's probably very little gene flow that takes place from one headwater stream to another headwater stream, even within the same drainage area. Even in the White Clay Creek basin, you'll find populations in first order streams that don't exchange gene flow with similar fishes in first order streams in the same drainage basin.

Not all headwater streams are fast-moving, high gradient; we have pools, wetlands areas, we have mud minnows and sticklebacks in there. We have them in West Virginia and Pennsylvania. These are very cold, slow-moving pools where fish live. We talked about differences and comparisons. Many of these fish are the same species that occur at other end of drainage, where they go into the Chesapeake Bay or the Gulf of Mexico -- forms which are sort of saltwater forms but their cousins or brothers or maybe even the same species occur at other end of the drainage. But again, there's very little gene flow or no gene flow from one population that lives in the first order stream and the population living near the Bay or Gulf.

We also find fishes in these headwater streams that are migratory. A lot of the lampreys, for example, occur in these small streams. In doing surveys in Pennsylvania, we're finding that a lot of lamprey populations have been deleted or extirpated -- some because of lampricide, some because of habitat changes that have occurred. We may not find adults there, but ammocoetes, which bury into the mud banks, are present. You'll find the adults there at certain times of the year when they migrate to breed. Some of the redhorse suckers you would also find in small headwater streams, especially those streams that empty directly into large rivers. We're doing some surveys of small streams that empty directly into the Allegheny, and the redhorse suckers, even the juveniles, are out of there by June or July. But early in the Spring, you can go to these streams that you wouldn't think would harbor fishes, and you'll find very large redhorse suckers, white suckers, hogsuckers, whatever.

We also have a series of madtoms. These are small catfish (*Noturus* sp.), and these fishes are unique and a lot of the populations are isolated from one another and are genetically and morphologically distinct -- we can tell them apart; and if they are isolated in these headwater streams they become particularly important.

This slide shows a *Phoxinus* species, a dace that appears in headwater streams. This form occurs in Tennessee, in just two small tributaries. Last week somebody sent me a *Phoxinus* from Virginia to identify, and it turned out to be an undescribed new species. A lot of us have spent a lot of time studying the fish in streams all over Virginia. You take a State with a well-described fish fauna like Virginia, and all of a sudden you come up with a whole new species! It was from a second-order stream. It's probably confined to that second-order stream, it probably occurs in no other second-order stream in the Clinch River.

We also have a series of dace - *Clinostomus* spp., a species that is found in first, second, and third order streams. Many of the populations are disjunct; you'll find them in one stream and you don't find them in another stream. So, there are a lot of fishes that are unique to these areas and we're making a mistake deciding to go into these areas and alter these streams until we have a really good knowledge what the fauna is, not just the insects but the fish. Fish are thought to be better known (fewer species, there's not so many life stages, it's easier to identify juveniles, etc.), and so on the surface you think, Oh, the fish fauna's pretty well known, and so if we wipe out this headwater stream we're not doing anything we're not going to be able to live with; we're not going to extirpate a species; and I just ask you to be a little cautious when you make that decision, because there are a lot of these unique populations that are called the same species but are different phenotypically, different genetically, and may in fact be a semi-species or even have achieved specific status at some point, maybe not in your lifetime but maybe in your grandchildren's lifetime. So it's something we need to preserve and something we need to examine.

I mention that and you might think, "Things don't evolve that fast." I also do a lot of work in Lake Malawi in Africa, and I'll tell you this quick story just to drive home my point. There's an island in Lake Malawi about 500 m from where my research station is. There are women in the village that talk about their fathers farming the land between where my research station is and that island. The island isn't very old; the lake water came up and made it an island. There are species of fish that occur at that island that occur nowhere else in Lake Malawi. We're talking about speciation that occurred within two generations of humans. So these things can happen very quickly.

When we look at assessment of ecosystems, the evolution assessments went from species/area curves, diversity indices, oligotrophic/heterotrophic ratios, Karr's biotic indices, etc.. When we look at flowing systems, we classify based on calcium content, distribution of fauna. First order streams generally have higher gradients than other orders, but we find exceptions. I studied a stream in the Conowingo Creek basin where the highest gradient was just where it went into the Susquehanna. We found headwater-type organisms -- so gradient has had a profound effect on the fauna found.

Why use fishes for study? Factors: they occupy the top of the food chain; they pass through other trophic levels; they are taxonomically well studied; there's generally more information available on life history.

Species succession in stream fishes is usually a factor of species addition rather than one of replacement.

I have been studying common shiners and striped shiners in headwater streams, in an area where there has been quite a lot of stream capture events among Atlantic Slope, Allegheny river, and Great Lakes drainages. In these areas I postulated that there would have been mixing of the populations and subsequent gene flow among them. I also found some other areas where we find a sibling species (one that morphologically resembles the common or striped shiner) where none of these so-called intergrades occur; thus, a distinct form is present. I have what I think is a new species where none were ever caught before. This occurred in headwater streams.

When looking at streams, as we go down through the drainage basin, we talk about the potential recovery of systems that have been damaged. I was successful in implementing such a program when I was at the University of Maryland, relative to giving mine permits. I persuaded the Maryland Bureau of Mines to give permits for one headwater area, and insisted that it be reclaimed, before a permit in an adjacent headwater area was granted, so we could save refugia in the system.

Cairns and Dickson proposed the concept of inertia -- how hard could we shove this system in terms of stress before structural components of the ecosystem change. They also talk about elasticity: How many times can we shove a system, how will that system recover. Another term is resiliency, defined as a rubber band snapping back. We can stretch the rubber band many times and it comes back; but we get to a point where the band breaks. Do streams act the same way? We don't understand that very well.

<u>Considerations associated with the concept of "inertia":</u>

1. Are the indigenous organisms accustomed to variations? Headwater streams are fairly stable, compared, for example, to estuarine environments. Estuarine organisms would be more used to varying conditions, and thus perhaps contribute more inertia to the system.

2. Structure - is there a lot of structural redundancy in the stream? I've been studying French Creek, a fourth order stream in northwestern Pennsylvania, one of the most diverse streams in the State. There's a lot of structural redundancy. In a particular riffle there are thirteen species of darters. There's a lot of functional redundancy -- they overlap a lot, do a lot of the same things. If you lose one species, it would probably not be as critical to French Creek as it would be to a headwater stream. A lot of these headwater streams (first and second order) have only two or three species of fish -- if you lose one of those species, you lose a third of your fauna, which is a structural change, and you lose a lot of functions as well, because there's not a lot of overlap. There's only one species of darter, or only one *Cottus* -- there's not thirteen of them. So it makes a more drastic impact.

3. The presence of buffered water antagonistic to toxic substances. Headwater streams don't have nearly the built-in protection -- physically or environmentally -- as fourth or fifth-order streams. A lot of these streams don't have the safeguards built into them to resist a functional or structural change.

4. How close the system is to a major ecological transitional threshold. We have a lot of headwater streams where the canopy has been removed, where the temperature in summer gets close to the lethal limit for brook trout; the winter limit gets close to the upper limit of egg production and embryo development. So that stream is close to a transitional threshold, and it won't take a lot of environmental change to push it over the edge.

5. The presence of a drainage basin management group with a water quality monitoring program. Headwater streams are vulnerable because they don't get a lot of attention from fishermen, biologists, etc., compared with larger downstream areas. A fish kill could happen in a headwater stream, and no one would know or call for remediation action.

<u>Considerations associated with the concept of "Elasticity"</u> (the parameters that play an important role in the ability of an ecosystem to recover once it's been damaged.)

1. Existence of nearby epicenters for providing organisms to reinvade a damaged ecosystem.

We can say that the Atlantic Ocean has a lot of inertia -- it's so big, it's well buffered, it can take a lot of stress without showing a change. What happens if the Atlantic Ocean is damaged - if it shows a structural and functional change? Where are the epicenters from which recolonization would take place? There aren't any. Take a headwater stream where *Phoxinus cumberlandensis* occurs. Talk about the unique insects that were talked about today -- they only occur in one place. There aren't other epicenters from which recolonization can take place if that stream is shoved functionally or structurally. Look at Pennsylvania, look at the stream maps. Some have dendritic networks; it looks like there are a lot of streams that could be a source for recolonization to take place. But what if that new species of mayfly only occurs in two of them? Where's recolonization going to take place? These streams are very fragile and have very low inertia, and I would also argue that their ability to recover is also compromised because they're so unique and so different.

2. Another thing that affects elasticity is mobility of any disseminules (life stages) of the organisms present. As I alluded to earlier, in those streams that were clearcut and flowing into the Potomac River in Maryland and West Virginia, the fish fauna was eliminated and so were aquatic insects. You can go back today and can find good aquatic insect populations, but they're still devoid of fish. Aquatic insects can fly and recolonize to some extent and even some of them are confined. Recolonization of fish could not take place, because they had to come up from one headwater stream to another and migrate through the Potomac River. With a pH of 4, that didn't happen very often. So, you have to look at the mobility of the life stages of the critters that inhabit these streams and the potential for them to get from one stream to another.

3. We have to look at the condition of the habitat following the stress. Question: if you put a stream on one of these benches, is it going to be the same? The condition of the habitat is going to be different -- you're not going to have the canopy, the gradient, the soils that you had. If you're a fish, you're not going to have the insects to support you -- it's going to change. So, those kinds of changes make a big difference on this recovery. And so, people say "recovery": Are we satisfied if something can live in the system? Are we satisfied if something different lives in the system but serves the same basic functions? Or do we want to define recovery as putting that stream or that ecosystem back to the way it used to be? These are several different levels that have quite different answers.

4. Elasticity -- The presence of residual toxicants. If you change the substrate, the soils, does that affect the ability of a particular stream to recover to the way it was before?

5. Chemical, physical environmental quality after the stress: How did we alter the system, and how is it physically or chemically different from the way it used to be?

6. Management or organizational capabilities for immediate control of the damaged area. Are there organizations there that will reintroduce the fauna? Are there organizations that know enough about how to introduce the native fauna? If we take brook trout and scatter them all over Pennsylvania and they interbreed with native brook trout populations, have we somehow diluted the gene pool of the native brook trout? Have you changed the ability of the native trout to inhabit that particular system?

These are all things that need to be considered in making a decision about the EIS, about recovery. You need to define recovery, and put in your minds "What kind of chance am I going to take with this ecosystem if I structurally or functionally change it?" and if I get to the probability where I do change it, no matter how small that probability may be, are there other refugia or other ways I can rehabilitate the system or reintroduce the fauna and flora to bring it back to its natural condition, or isn't this even an important question to ask? It makes a big difference if there are unique fauna in that stream. I would argue that, if there's a headwater stream that's the only stream in the world that contains this particular species, we're not going to take any chance with it. And if you want to mine coal or gold or silver or whatever under that stream, we're not going to allow you to do that, because we're not going to take a chance that we're going to lose that genetic diversity of this fish, this mayfly, or this stone fly, or whatever.

WALLACE - I WOULD ADD ANOTHER VERTEBRATE TO THAT GROUP -- SALAMANDERS. THEY ARE VERY LIMITED TO A FEW LOCATIONS IN THE APPALACHIANS. **STAUFFER** - RIGHT. A LOT OF HELLBENDER POPULATIONS ARE REALLY ISOLATED AND DISJUNCT FROM ALL OTHER POPULATIONS.

HANDEL - IS THERE A MINIMUM SIZE STREAM THAT CAN SUPPORT A FISH COMMUNITY? **STAUFFER** - NO. THERE ARE SOME SMALL STREAMS THAT DON'T SUPPORT FISH COMMUNITIES, BUT I'VE FOUND FISH COMMUNITIES IN BASICALLY SINKHOLES. WE WERE SPEAKING OF INTERMITTENT STREAMS, WHERE THE STREAMS DRY UP AND YOU THINK THERE'S NO FISH IN THEM, BUT YOU KEEP GOING BACK YEAR AFTER YEAR, AND YES THERE ARE. THERE ARE SOME FISHES IN FLORIDA (*JORDANELLA*) THAT HAVE -- FOR LACK OF A BETTER TERM -- ANIMAL SEED, AND CAN LIVE FOR ONE YEAR IN TRULY INTERMITTENT STREAMS. THEY LAY THEIR EGGS, THE EGGS SINK DOWN INTO THE MUD, THEY AESTIVATE AND DRY UP. WHEN THE RAINS COME AGAIN THE EGGS HATCH, AND *JORDANELLA* ARE BACK IN THE STREAM. SOME OF THE WORK THAT WE DID IN DROUGHT PERIODS, WHERE WE FOUND RIFFLE SECTIONS IN WEST VIRGINIA, WE FOUND A STREAM THAT HAD A POOL HERE, AND A POOL THERE, BUT NO RIFFLE CONNECTING THE POOLS. I THOUGHT THE DARTERS HAD TO BE IN THE POOLS. WE SAMPLED AND WE DIDN'T FIND THEM. I THOUGHT SURELY THE DARTERS HADN'T BEEN ELIMINATED FROM THE SYSTEM, AND OUT OF DESPERATION I STARTED SHOVELING RIFFLES: ABOUT 5 HOURS AND 2 FEET LATER, I FOUND THE DARTERS AMONG THE GRAVEL. **HANDEL** - WOULD YOU POINT-BLANK SAY THAT IN APPALACHIA THERE IS NO STREAM SYSTEM TOO SMALL TO BE IMPORTANT FOR FISH CONSERVATION? **STAUFFER** -YES, I WOULD MAKE THAT STATEMENT.

Discussion: what is a stream. What kind of input do the regulatory agencies need from this assembled group to make the decisions they need to make on permits in the interim while the EIS is being developed?

Passmore - For our work that we've done in permit reviews and preliminary data collection that we've done, we've used West Virginia's definition in their water quality standards when they define intermittent and perennial. We know that flow alone is not a good indication of the function of streams. West Virginia water quality standards define Intermittent streams as streams which have no flow during long periods of no precipitation, and do not contain aquatic organisms whose life histories require more than 6 months in flowing water. For one of the permits, we looked at a lot of streams that were intermittent in terms of flow, with a few residual pools here and there, but we didn't classify one of those as intermittent under West Virginia standards. They all contained many aquatic organisms, and certainly many whose life histories require more than 6 months of flowing water. The West Virginia water quality standards have an ecological connect to them.

Tibbott - Is that consistent across all of the states that we're dealing with in this EIS?

Hanmer - No. The West Virginia and the Pennsylvania standards are the ones we found that try to mix flow regime and biology, and what they've wound up doing is bastardizing the English language, because by trying to distinguish between perennial and intermittent -- for example, the surface mining regulations are the ones that make distinctions between perennial, intermittent, and ephemeral. Now how these definitions affect the regulatory regime is unknown. Most water quality and environmental regulations don't use these terms in a regulatory sense. So, one of the things we're struggling with is, rather than try to say that something is "perennial and therefore . . .," meaning anything different than what it says in the dictionary, which is that it flows all the time, is to find another way of talking about the biological values that don't trip over these older terms and older words. So, I think we do need to look for some language.

Tennessee is interesting because they don't have any definition, other than "waters." They're trying to define something called a "de minimis" stream, and trying to define that right now. they're Thinking of it in terms of having a drainage area of 20 acres.

From the standpoint of the 404 program and water quality standards, it's more important to describe the functional values, rather than trying to put a name on it like perennial or intermittent. From the standpoint of reviewing regulations, we don't have good definitions. It would be nice to have an "Appalachian coal field" definition, or a common sense definition based on some other geographic scale. In Kentucky, according to people we talked to, they define regulated surface waters of the Commonwealth as the blue line streams on a USGS topo map, or a discrete conveyance with a defined channel, field-confirmed. Statistical recurrence of low flow does not enter into the definition of a stream. So, there's not a single state in this region that does it the same way [as another state].

Wallace - Does EPA have a definition of a stream, other than Army Corps standards? **Hanmer** - We have a definition of waters of the United States in Corps and EPA regulations. But, you have to go out and define what you're trying to protect on an area by area basis. Our definitions tended to be broad, to allow for going out and making more specific definitions.

Wallace - Luna Leopold in 1994 pointed out in his book "A View of the River" that all of these blue lines on USGS maps are much smaller than actual stream flows, actually much smaller than perennial flow. They were not done by field work, they were drawn in the laboratory. They basically assigned "what is a stream" to someone sitting inside in a laboratory drawing a map.

Hanmer - I think you do want to say what is the impact? Before you define "what is a stream," you ask "why do I care?" And the reason you care, from a regulatory standpoint, is that you're trying to

FIGURE OUT HOW TO REGULATE SOME KIND OF PERTURBATION. MINING COMPANIES ARE IRRITATED THAT SOME OF THE SAME PERTURBATIONS ARE DEFINED AS NON-POINT SOURCES UNDER THE CLEAN WATER ACT AND THEREFORE NOT REGULATED, AND ARE DEFINED AS POINT SOURCES UNDER THE CLEAN WATER ACT AND ARE REGULATED, AND IT SEEMS ARBITRARY. AND IT IS, TO A CERTAIN DEGREE, ARBITRARY. HERE WE'RE TRYING TO DISCUSS PHYSICAL PERTURBATIONS. WATER QUALITY STANDARDS WERE DEVELOPED WITHOUT MUCH CONSIDERATION FOR PHYSICAL IMPACTS, THEY WERE DEVELOPED TO CONTROL CHEMICAL INPUTS, AND THEY WERE MOSTLY CONCERNED WITH DEFINING LOW FLOW FOR THE PURPOSE OF SAYING WHEN STANDARDS WOULD BE ALLOWED TO BE VIOLATED. SO THE HISTORY OF THIS WAS A DEVELOPMENT UNDER A "LOGIC STREAM" FOR A PURPOSE. NOW WE NEED A NEW "LOGIC STREAM" THAT SAYS WE'RE CONCERNED ABOUT PHYSICAL PERTURBATIONS, PHYSICAL DESTRUCTION, AND THEREFORE, YOU SAY WHAT KIND OF LOGIC, WHAT KINDS OF DEFINITIONS DO YOU WANT TO CONSTRUCT IN A CASE LIKE THAT. AND THE MOST IMPORTANT QUESTION FOR US IN TERMS OF MITIGATION AND PREVENTION IS THE WORD "SIGNIFICANCE" -- IN OTHER WORDS, IT'S NOT THE MERE EXISTENCE, IT'S ALSO THE SIGNIFICANCE, BECAUSE AT THE END OF THE DAY IF YOU WANT TO STOP SOMETHING FROM HAPPENING, THEN YOU HAVE TO TALK ABOUT SIGNIFICANT ENVIRONMENTAL IMPACT AND WHAT DO YOU MEAN BY THAT.

PASSMORE - IN WATER QUALITY STANDARDS, THERE ARE FOUR COMPONENTS: NARRATIVE CRITERIA (SEDIMENTS, SOMETIMES TOXICS), NUMERIC CRITERIA (MORE TRADITIONALLY WHAT PEOPLE THINK ABOUT AS WATER QUALITY STANDARDS, FOR EXAMPLE DISSOLVED OXYGEN CAN'T BE LESS THAN 5 MG/L), AND DESIGNATED USES, WHICH IS VERY IMPORTANT AND OFTEN WHAT WE'RE TRYING TO PROTECT AND MOST STATES HAVE A BLANKET DESIGNATED USE FOR ALL OF ITS WATERS THAT SAYS THAT THE STREAM HAS TO SUPPORT THE AQUATIC LIFE THAT SHOULD BE THERE. THE AQUATIC LIFE DESIGNATED USE IS OFTEN THE STANDARD WE USE WHEN WE THINK ABOUT WHAT WE'RE TRYING TO PROTECT. IF THE AQUATIC LIFE IS THRIVING AND DOING WELL, WE FEEL THAT THE OTHER PARAMETERS ARE PROBABLY DOING WELL. AND THE FOURTH IS ANTIDEGRADATION. SO, THERE ARE AT LEAST FOUR ELEMENTS OF WATER QUALITY STANDARDS, AND THE TRADITIONAL CHEMISTRY IS ONLY A TINY PART OF WATER QUALITY STANDARDS.

QUESTION - WHAT ARE SOME OF THE CRITERIA THE EPA USES FOR THE BIOLOGICAL ASSESSMENT? A SIGNIFICANT CHANGE FROM WHAT WOULD BE NORMAL? THERE REALLY AREN'T ANY ESTABLISHED BIOLOGICAL CRITERIA.
PASSMORE - MOST OF THE STATES HAVE SOME TYPE OF NARRATIVE CRITERIA THAT COVERS AQUATIC LIFE.

HANMER - WHEN YOU ARE CONTEMPLATING THE PHYSICAL DESTRUCTION OF A STREAM, WHICH IS WHAT YOU HAVE WHEN YOU HAVE A FILL, THERE'S ANOTHER SECTION OF THE LAW WHICH CONTAINS THE RULES, AND IT'S SECTION 404. THE FIRST THING YOU HAVE TO CONSIDER ARE THE 404(B)(1) GUIDELINES, WHICH ARE AVOIDANCE- OR TECHNOLOGY-BASED: WHY IS IT THAT YOU HAVE TO FILL IN THE STREAM? WHAT ARE THE ALTERNATIVES? WHAT CAN YOU DO TO AVOID THE IMPACT? SO YOU DRIVE MINIMIZE, MINIMIZE, MINIMIZE AS FAR AS YOU CAN GO, AND THEN YOU SAY WELL, THIS ACTIVITY HAS TO TAKE PLACE HERE (FOR EXAMPLE, THIS IS WHERE THE COAL SEAM IS), AND THIS IS THE SIZE OF THE OPERATION YOU GET TO THE POINT WHERE YOU ARE CONVINCED THAT THE ECONOMICS OF THE OPERATION WOULD NOT TAKE PLACE BUT FOR THE FILL. AT THAT POINT, YOU'VE FINISHED THE MINIMIZATION JOB, AND YOU SAY WHAT CAN BE DONE TO AMELIORATE THE IMPACTS TO TRY TO DETERMINE WHAT IS THE LONG-TERM, PERMANENT IMPACT HERE (WHICH GIVES YOU AN INTENSE INTEREST IN QUESTIONS LIKE WHAT IS THE EFFECTIVENESS OF LONG-TERM RESTORATION TECHNIQUES). AND THEN FINALLY, ONCE AN APPLICATION PASSES THROUGH ALL OF THOSE TRIGGERS, THERE MAY BE A CIRCUMSTANCE WHEN THE GOVERNMENT WILL STILL NOT ALLOW THE IMPACT TO TAKE PLACE: THAT'S WHERE YOU GO TO THE ENVIRONMENTAL TRIGGER, AND THAT TRIGGER HAS THE WORD "SIGNIFICANT" IN IT, AND NO ONE KNOWS HOW TO DEFINE IT EXCEPT ON A CASE-BY-CASE BASIS. THIS IS WHY WE'VE BEEN ACCUSED OF NOT CARING ENOUGH ABOUT INSECTS, BUT GENERALLY "SIGNIFICANCE" IS NOT A SCIENTIFIC TERM; IT'S A VALUE-LADEN, PUBLIC-RELATIONS... IT HAS A LOT IN IT BESIDES SCIENCE. BUT THE KIND OF CONVERSATION WE'VE HAD THIS MORNING IS INFORMING THE WHOLE CONVERSATION ABOUT WHAT SIGNIFICANCE IS. BUT THE WATER QUALITY STANDARDS BASICALLY GO AWAY, ONCE YOU HAVE SAID "YES" UNDER 404(C), YOU'VE TURNED A WATER OF THE UNITED STATES INTO A LAND OF THE UNITED STATES -- IT NO LONGER IS A WATER OF THE UNITED STATES -- AND THEN THE WATER QUALITY STANDARDS PICK UP BELOW. THERE'S ONLY ONE CIRCUMSTANCE UNDER THE CLEAN WATER ACT WHERE WATER QUALITY STANDARDS CEASE TO EXIST, AND THAT'S WHEN WATER CEASES TO EXIST, AND IT'S ONLY SECTION 404 WITH ITS OWN SET OF REGULATIONS AND GUIDELINES, THAT DEFINES THE CIRCUMSTANCES UNDER WHICH ECONOMIC ACTIVITY IN THE UNITED STATES WILL BE ALLOWED TO DISPLACE A WATER. UNFORTUNATELY, THERE IS MUCH OF THIS GOING ON THAT'S UNREGULATED, BECAUSE IT'S CALLED NON-POINT SOURCE. THERE ARE LOOPHOLES UNDER THE LAW WHERE STATES ARE SUPPOSED TO BE REGULATING, FOR EXAMPLE AGRICULTURE OR OTHER ACTIVITIES -- BUT THEY AREN'T. THERE ARE LOSSES -- DRAINAGE IS OCCURRING IN NORTH CAROLINA ON AN ABSOLUTELY AWESOME SCALE --

AND THAT'S LOSS BY SUCKING IT OUT RATHER THAN FILLING IT IN. IT'S OFFENSIVE, BUT UNDER THE LAW YOU'RE SUPPOSED TO GET A 404 PERMIT AND IF YOU GET ONE YOU COULD BE ALLOWED TO FILL AND THEREFORE IT BECOMES A LAND OF THE UNITED STATES.

WALLACE -EXPLAIN NATIONWIDE 26? **HANMER** - ALL OF THE REGULATORY AGENCIES, THE CORPS AND EPA, BEGAN TO LOOK FOR WAYS TO PERMIT LARGE GROUPS OF WHAT WE CONSIDERED DE MINIMIS ACTIVITIES, OR ACTIVITIES THAT WERE SO SIMILAR TO EACH OTHER THAT YOU COULD WRITE A BLANKET REGULATION RATHER THAN HAVE TO ISSUE HUNDREDS OF THOUSANDS OF INDIVIDUAL PERMITS. THE CORPS STARTED OUT WITH 5 CFS, BY TRYING TO DEFINE DE MINIMIS IN TERMS OF THE GEOGRAPHIC AREA AFFECTED, WHICH COULD BE AFFECTED BY A VARIETY OF DIFFERENT FILLING TYPES OF ACTIVITIES. NATIONWIDE 21 IS FOR SURFACE MINING ACTIVITIES REGULATED UNDER SMCRA. IT WAS DONE WHEN SMCRA WAS STILL LARGELY A FEDERALLY-REGULATED PROGRAM. THE RATIONALE WAS THAT THE SMCRA PROCESS AND NEPA SHOULD INCORPORATE ALL THE TYPES OF CONSIDERATIONS THAT WERE RELEVANT TO PROTECTING THE ENVIRONMENT, AND IF IT DID, THEN THE CORPS WOULD NOT IMPOSE A SECOND NEW NEPA REVIEW ON EVERYTHING, BUT WOULD ACCEPT THE RESULTS OF THE SMCRA PROCESS AND AUTOMATICALLY PERMIT. NP 21 SEEMS TO BE A MOSTLY AUTOMATIC PERMIT THAT WAS TACKED ONTO THE END OF A SMCRA PERMIT. THE PROBLEM WAS (THIS IS NOT A CRITICISM OF THE STATES) THAT AS WE DELEGATED TO THE STATES, SOME OF THE ENVIRONMENTAL REQUIREMENTS ASSOCIATED WITH NEPA "FELL OFF," AND A FEW QUALITATIVE DIFFERENCES OCCURRED, AND THE FEELING WAS THAT WE WERE LOSING SOMETHING, PERHAPS.

POLITAN - BEFORE A SECTION 404 PERMIT IS VALID, A STATE MUST ISSUE 401 WATER QUALITY CERTIFICATION FOR THE PROJECT, AND CERTIFY THAT THE PROJECT COMPLIES WITH STATE WATER QUALITY STANDARDS. SO EACH STATE CAN MANAGE ITS RESOURCES THAT WAY. THAT'S WHERE WE GET INTO THE DIFFERENT TERMS, DOES IT COMPLY WITH WATER QUALITY STANDARDS?

HANMER - ONE OF THE FACTORS WITH SECTION 404 IS THAT THE STATE HAS AN EFFECTIVE VETO OVER THE ISSUANCE OF A 404 PERMIT. TAKE TROUT STREAMS -- FOR EXAMPLE, IF STATES TRY TO USE THEIR WATER QUALITY STANDARDS TO SAY NO TO ALL TYPES OF FILL, THE STATE LEGISLATURE PROBABLY VERY QUICKLY DOES SOMETHING TO THAT STATE AGENCY. BUT THE STATES ARE EXPECTED TO IDENTIFY SPECIAL WATERS, AND YOU GET INTO WHAT DO YOU MEAN BY THAT, TROUT STREAMS? WHAT HAVE PEOPLE BEEN WILLING TO DESIGNATE IN THEIR STANDARDS AS SPECIALLY-PROTECTED WATERS.

AS A REGULATOR, THE QUESTION IS, WHAT DO BIOLOGISTS HAVE TO TELL US THAT CAN BE USED TO DETERMINE SIGNIFICANCE OR VALUES THAT NEED TO BE PROTECTED? SO IT'S A WAY OF DEFINING, BUT IT'S NOT THE SAME THING AS A DEFINITION.

QUESTION - IS THERE AN UNDERLYING ASSUMPTION IN THIS APPLICATION OF THE LAW THAT HEADWATER STREAMS ARE LESS IMPORTANT THAN LARGER STREAMS? **HANMER** - YES, IN MY EXPERIENCE OVER THE LAST 25 YEARS, I WOULD SAY THAT IS DEFINITELY THE CASE. **COMMENT** - IN WEST VIRGINIA, UNTIL RECENTLY, THOSE HEADWATER STREAMS WERE ALSO GIVEN A DIFFERENT DESIGNATED USE (THEY WERE CALLED "BAIT MINNOW STREAMS") WHICH DIMINISHED THEIR IMPORTANCE. **PASSMORE** - BUT, THEY STILL HAD TO MEET ALL THE AQUATIC LIFE CRITERIA. **QUESTION** - SO IF THERE WERE A PERMIT APPLICATION TO DESTROY A FOURTH-ORDER STREAM, THERE WOULD BE A DIFFERENT SET OF CRITERIA APPLIED? **HANMER** - I WOULD SAY AUTOMATICALLY YES, BECAUSE THE NATIONWIDE PERMIT ORIGINALLY SAID THAT IF THE WATER BODY FLOWED LESS THAN 5 CFS, IT WAS A DE MINIMIS WATER BODY, AND A DE MINIMIS WATER BODY TRANSLATED INTO A DE MINIMIS EFFECT. I THINK THAT WAS SCIENTIFIC IGNORANCE -- THAT'S WHAT YOU'RE TRYING TO TELL US. I MUST TELL YOU THAT HEADWATER STREAMS ARE BEING DESTROYED EVERYWHERE -- FOR WATER SUPPLY RESERVOIRS, EVER PLACE YOU LOOK. IT'S AN AREA THAT BEGAN TO WORRY US SOME YEARS AGO BUT WE DIDN'T KNOW WHAT TO DO WITH IT. WE STILL HAVEN'T KNOWN QUITE WHAT TO DO WITH IT UP UNTIL TODAY, WHICH IS WHY THIS MEETING IS A GOOD MEETING.

POMPONIO - A COUPLE OF POINTS: THE CORPS DID WHAT THEY DID BECAUSE THE VOLUME OF PERMITS THE CORPS EXPECTED TO HAVE TO PROCESS IF THEY HAD TO DO PERMITTING WORK ON ALL THE LOCAL LITTLE THINGS THAT WENT ON, AND THE CONCERN THAT THE FEDERAL GOVERNMENT DIDN'T REALLY BELONG WAY UP IN THE LITTLE HEADWATER STREAMS REGARDLESS OF THE ECOLOGICAL REASONS, BASED ON WHERE FEDERAL INTERVENTION SHOULD OCCUR. IT WASN'T A TOTALLY ECOLOGICAL DECISION ONE WAY OR ANOTHER -- IT WAS A PRACTICAL DECISION. ALSO, THE NATIONWIDE PERMITS NEVER SAID THEY WEREN'T WATERS OF THE UNITED STATES, AND THAT THE CORPS COULDN'T

REGULATE THEM, THE CORPS CAN TAKE DISCRETIONARY AUTHORITY ON ANY AREA. NP 26 GAVE EVERYONE CARTE BLANCHE TO WORK ABOVE THE HEADWATERS, AND NP 21 GAVE MINING COMPANIES EVEN MORE OPPORTUNITY TO DO THINGS IN EVEN LARGER STREAMS.

COMMENT - SO IF THERE'S AN UNDERLYING BIAS AGAINST HEADWATER STREAMS THAT DOES NOT COME FROM A SCIENTIFIC BASIS, THEN THIS ISN'T A SCIENTIFIC ISSUE SINCE DESTROYING THE WATERS OF A SMALL STREAM, FROM A SCIENTIFIC STANDPOINT, ISN'T ANY DIFFERENT THAN DESTROYING THE WATERS OF A LARGE STREAM. IN A SENSE, WE'RE BEING ASKED AS SCIENTISTS TO COUNTERACT A MAJOR SOCIAL BIAS OR A BIAS CONSTRUCTED FOR PURELY ECONOMIC REASONS, THAT HAS NOTHING TO DO WITH THE SOCIAL VALUE OF THE SYSTEM, OR THE SCIENTIFIC VALUE.

HOFFMAN - BUT THE 404 PROGRAM WAS THOUGHT ORIGINALLY TO EXTEND ONLY TO NAVIGABLE WATERS, SO THERE WAS ALWAYS A BIAS AGAINST HAVING FEDERAL INTERVENTION IN THE UPPERMOST HEADWATER AREAS. THAT COUPLED WITH THE WORK LOAD ISSUE, DROVE THE CORPS TO DEVELOPING NP 26. BUT NP 26 ALSO HAS THE PROVISION OF BEING REVIEWED EVERY SO MANY YEARS, AND AS A RESULT OF THE AGENCIES PROVIDING INFORMATION ON THE IMPACTS, AND DEMONSTRATING THAT THEY WERE CUMULATIVELY SIGNIFICANT, THAT'S WHY THEY WENT INTO REVISING THE EXISTING NP 26 INTO THE FORM THAT IT HAS NOW, WHICH IS GOING TO BE ARGUED AGAIN. WHAT THEY'RE DOING NOW IS CONSIDERING EXPANDING IT INTO ALL HEADWATER AREAS, BUT SAYING THAT ANYTHING LESS THAN AN ACRE IS OK TO FILL.

POMPONIO- ONE OF THE REASONS THE FEDERAL GOVERNMENT COULD GET AWAY WITH EXEMPTING ALL OF THAT ACTIVITY ABOVE THE HEADWATERS IS THAT NO ONE CONVINCED THE DECISION-MAKERS WHO WERE NOT FIELD BIOLOGISTS OR AQUATIC SCIENTISTS, THAT THERE WAS ANYTHING SPECIAL ABOUT THOSE AREAS. COMMON KNOWLEDGE AND SCIENTIFIC RESEARCH ALWAYS SEEMED TO BE FOCUSED ON THE LARGER WATERS. ALTHOUGH THEY HAD AN INTUITION ABOUT THE VALUE OF THOSE AREAS, THEY COULD EASILY DISMISS AREAS ABOVE THE HEADWATERS. NEED TO DO A BETTER JOB OF EXPLAINING WHY THEY'RE IMPORTANT. IF THERE'S MORE UNDERSTANDING OF THE VALUE OF THESE AREAS, IT WILL EXTEND FAR BEYOND JUST MINING ISSUES.

HANMER - THERE'S UTILITY VALUE, TOO. ENVIRONMENTAL PROGRAMS, OLDER ONES, EVEN GOT PAID FOR, MAYBE EVEN STILL DO, GOT PAID FOR FROM SALES OF FISHING LICENSES. CORPS OF ENGINEERS BENEFIT STUDIES: YOU WEREN'T JUST LOOKING AT FISH, YOU WERE LOOKING AT WHETHER THERE WAS FISHING; NOT JUST WHETHER IT WAS SWIMMABLE, BUT WHETHER THERE WAS SWIMMING. COULD YOU ASSIGN ECONOMIC VALUES TO THESE WATER BODIES THAT WOULD THEN INCREASE THEIR "VALUE" THAT WOULD THEN OFFSET THE OPPORTUNITY COSTS YOU WOULD HAVE OF REFUSING TO ALLOW THEM TO BE EXPLOITED FOR MINING OR OTHER PURPOSES. BECAUSE A LOT OF THE DECISION-MAKING PROCESS IS SOCIO-ECONOMICS.

EVERY TIME WE GET CLOSE TO FARMING AND FORESTRY WITH THE CLEAN WATER ACT, WE FIND OURSELVES IN POLITICALLY DANGEROUS TERRITORY, SO THESE HEADWATERS STREAMS PROBABLY LOOK LIKE SOMEBODY'S FARM OR SOMEBODY'S SACRED PROPERTY.

WE NEED TO TELL A BIOLOGICAL VALUE STORY THAT WILL ENRICH OUR UNDERSTANDING OF STREAMS, IF NOT OUR DEFINITION. "A STREAM LOOKS LIKE A PILE OF WET LEAVES," RIGHT?

HARTOS - WHAT DOES THE CORPS RELY ON TO DEFINE A JURISDICTIONAL STREAM? DO YOU RELY ON THE STATE STANDARDS? **POLITAN** - DON'T THEY USE THE ORDINARY HIGH-WATER MARK? [IN RESPONSE, CORPS PERSONNEL INDICATED THAT THEY PERSONALLY ARE NOT INVOLVED WITH PERMITTING, AND COULDN'T REALLY ANSWER THE QUESTION.]

HANDEL - WE HAVE FORMAL DEFINITIONS OF WETLANDS, A FEDERAL MANUAL THAT'S ENORMOUS THAT DEFINES WETLANDS BY HYDROLOGY, VEGETATION, AND SOIL CHARACTERISTICS. MANY SMALL STREAMS HAVE WETLANDS ASSOCIATED WITH THEM. ARE THERE STREAMS THAT DON'T HAVE WETLANDS? SO IS THE ISSUE REALLY TO DEFINE THOSE HEADWATER STREAMS THAT DON'T HAVE WETLANDS ASSOCIATED WITH THEM? **HANMER** - PROBABLY YES. **POMPONIO** - IF WE CAN DEFINE WETLANDS BY SOILS, VEGETATION AND HYDROLOGY, IS THERE AN ANALOGOUS SET OF PARAMETERS WE CAN USE TO DEFINE A STREAM? SOMETHING ANALOGOUS TO AN OBLIGATE HYDROPHYTE? LIKE FLOW REGIME, ETC.? **WALLACE** - THE WEST VIRGINIA DEFINITION IS VERY GOOD, IT MAKES A LOT OF SENSE, IT MAYBE EVEN TOO RESTRICTIVE!

HANMER - THE PROBLEM IS THAT THEY USED IT IN ASSOCIATION WITH THE WORD INTERMITTENT -- KIND OF A NON-DEFINITION, IT SAYS IT'S NOT INTERMITTENT, BUT IT DOESN'T REALLY SAY WHAT IT IS.

TIBBOTT - SHOULD WE HAVE A BIOLOGICALLY-BASED DEFINITION? **COMMENT** - A FUNCTIONAL DEFINITION. **POLITAN** -- IF WE USE A BIOLOGICAL DEFINITION, WHAT HAPPENS TO STREAMS DEVOID OF LIFE DUE TO AMD? **ANSWER** - THAT'S AN IMPAIRMENT. **HANMER** - ARE ANY OF THOSE SITUATIONS NATURALLY-OCCURRING? **POLITAN**-- I'VE NEVER SEEN A NATURAL AMD SITUATION THAT WIPED OUT A STREAM. **POMPONIO** - EVEN THE WETLANDS DEFINITION INCLUDES THE PHRASE "UNDER NORMAL CIRCUMSTANCES."

TIBBOTT - I WOULD THINK THAT ONE OF THE RECOMMENDATIONS WHICH COULD COME OUT OF THE EIS WOULD BE A DEFINITION OF A STREAM ACROSS PROGRAMS AND ACROSS STATES. **WALLACE** - IT'S VERY DANGEROUS TO HAVE ONE DEFINITION THAT COVERS ALL TYPES OF AREAS. THERE ARE SOME AREAS IN THE COASTAL PLAIN OF GEORGIA WHERE STREAMS ARE DRY FOR PART OF THE YEAR. **COMMENT** - BUT IF WE'RE JUST DEVELOPING A DEFINITION FOR THE AREA OF STEEP SLOPE MINING, IS IT POSSIBLE TO DO? **HANMER** - AS A PRACTICAL MATTER, I CAN'T SEE HOW WE'RE GOING TO GET ALL THE STATES IN THIS REGION TO CHANGE ALL THEIR REGULATIONS TO A CONFORMING DEFINITION. IT WOULD BE A WASTE OF TIME TO TRY THAT, BUT IT WOULD BE USEFUL TO COME UP WITH A GUIDELINE FOR ALL THE STATES TO DETERMINE WHEN THEY SHOULD BE CONCERNED ABOUT THESE STREAMS AND WHY. REOPENING THEIR WATER QUALITY STANDARDS IS DANGEROUS. **POLITAN** - WE DO IT EVERY THREE YEARS ANYWAY. **HANMER** - YES, BUT YOU DON'T OPEN UP THE DEFINITION OF WHAT IS A STREAM EVERY THREE YEARS.

ARWAY - I DON'T KNOW WHY YOU CAN'T USE THE SAME SYSTEM AS WHEN REGULATING DISCHARGERS -- THAT IS, TO ASSIGN THE "POINT OF FIRST USE" -- WHEREVER THERE IS A USE IS WHERE THE STREAM STARTS FROM A REGULATORY PERSPECTIVE. **QUESTION** -- WHAT IS THE "POINT OF FIRST USE" IN PENNSYLVANIA? **ARWAY** - IT'S A VERY SUBJECTIVE DEFINITION EMBODIED WITHIN THE REGULATORY PROGRAM THAT ALLOWS THE FIELD BIOLOGIST TO USE PROFESSIONAL JUDGEMENT TO ASSIGN WHERE A PERENNIAL STREAM STARTS AND WHERE THE WATER QUALITY STANDARDS ARE APPLIED. **RAMSEY** - IN WEST VIRGINIA, THAT "BEST PROFESSIONAL JUDGEMENT" BECAME 250 ACRES, SO THERE'S A REAL DANGER IN DOING THAT. **HANMER** - AND IN KENTUCKY, IT'S THE BLUE LINE. SO, IF YOU WANT TO WORK ON THIS, WHEN IS IT YOU KNOW YOU'RE SEEING SOMETHING YOU WANT? I DON'T THINK THAT ANY OF THESE DEFINITIONS IS THE PROBLEM. THE PROBLEM IS ASSIGNING VALUE FOR MITIGATION AND FOR MAKING PERMITTING DECISIONS.

COMMENT - THERE ARE SCIENTISTS HERE THAT TALK ABOUT HEADWATER STREAMS DISTRIBUTING NUTRIENTS, ETC. -- THAT'S NOT A SOCIETAL VALUE JUDGEMENT ABOUT WHAT'S IMPORTANT. WE KNOW THINGS WILL CHANGE WITH THIS TYPE OF ALTERATION OF THE LANDSCAPE, BUT WHETHER OR NOT SOCIETY WILL ACCEPT IT . . . THAT'S ALL WE CAN DO AS SCIENTISTS. **HANMER** - THAT'S RIGHT, BUT THE INFORMATION THAT WAS PRESENTED THIS MORNING IS NOT GENERALLY KNOWN, SO THAT SIDE OF THE CONVERSATION NEEDS BEEFING UP, COMPARED TO PEOPLE WHO SAY THEY OWN THE LAND AND SOMETIMES IT'S WET AND SOMETIMES IT'S DRY. THERE'S A RICH OPPORTUNITY TO INFORM THIS DECISION-MAKING PROCESS FROM THE SCIENTIFIC PROCESS.

COMMENT - WHY ARE INTERMITTENT STREAMS ASSUMED TO BE UNIMPORTANT? **HANDEL** - IT'S ANALOGOUS TO VERNAL POOLS, WHICH HAVE CRITICAL ECOLOGICAL VALUE, BUT ONLY IN A CERTAIN SMALL TIME OF YEAR. THERE ARE CERTAIN STREAMS WHICH ARE DRY FOR MANY MONTHS, BUT STILL HAVE BIOLOGICAL INTEREST. **COMMENTER** - BUT IT'S AS IF WE'RE EXCLUDING INTERMITTENT AS BEING IMPORTANT, IN THESE DEFINITIONS. WHY ISN'T INTERMITTENT AS IMPORTANT AS PERENNIAL? **HANMER** - THAT'S A MISUNDERSTANDING. MOST OF THE STATE WATER QUALITY STANDARDS DO NOT DISTINGUISH -- THEY DON'T TRY TO DEFINE INTERMITTENT AND PERENNIAL AND EPHEMERAL FOR PURPOSES OF THE REGULATORY EFFECT. THE SURFACE MINING REGULATIONS DO -- I DON'T KNOW WHAT EFFECT THEY GIVE THOSE DEFINITIONS, BUT THE CLEAN WATER ACT DEFINITIONS ARE NOT BASED ON THE FLOW. MOST OF THE STATES DID NOT TRY TO DO THAT; WEST VIRGINIA IS ACTUALLY THE EXCEPTION IN THIS LIST OF STATES THAT USE THE TERM "INTERMITTENT" IN THEIR WATER QUALITY STANDARDS. THE REST JUST LEFT IT ALONE.

WALLACE - WHAT'S WRONG WITH THE WEST VIRGINIA DEFINITIONS? **HANMER** - WHAT IS THE DEFINITION USED FOR? THE DEFINITION IS "STREAMS WHICH HAVE NO FLOW DURING SUSTAINED PERIODS OF NO PRECIPITATION AND WHICH DO NOT SUPPORT AQUATIC LIFE WHOSE LIFE HISTORY REQUIRES RESIDENCE IN FLOWING WATERS FOR A CONTINUOUS PERIOD OF AT LEAST 6 MONTHS." WHY DOES WEST VIRGINIA USE THAT DEFINITION? **POLITAN** - IT'S WHERE WATER QUALITY STANDARDS APPLY. **HANMER** - SO YOU START WATER QUALITY STANDARDS AT THAT POINT? **POLITAN** - NO.

If there's an aquatic insect that requires 4 months of flowing waters, it's an intermittent stream, that means that if you do something to that stream, we consider it a significant loss to the state, we want compensation for it, or it mandates protection -- we may deny you doing anything in there. **Hanmer** - So you use it kind of like Pennsylvania uses "point of first use" -- it's your point of first use? **Politan** - Kind of. Wet weather streams are "streams that flow only in direct response to precipitation, or whose channels are at all times above the water table." **Passmore** - And what happens to those streams in your regs as opposed to intermittent? **Politan** - If we find aquatic life ... **Passmore** - I think people in the room are thinking that there's a distinction between intermittent and perennial, when there isn't -- there's a distinction between intermittent and ephemeral, so people are misunderstanding that they're cutting off intermittent streams, when they're not. **Politan** - ... at least in West Virginia.

Commenter - Well, in the case at hand, are we talking about being able to prevent valley fills in all streams that are actually called streams? Maybe we shouldn't be talking about the definitions, but what we can actually do here . . . It's not quite clear to me whether we've completely given up the probability of putting an end to this process of destroying streams. It seems to me that we have a reasonable crack at making a case, from the standpoint of the Clean Water Act and the values to the environment of headwater streams, that this process shouldn't occur at all. That's the first stage. If the Environmental Impact Statement can find those results and actually make a case that this process should be stopped, it should be stopped. Otherwise, then we have to get into another level of discussion, of how you sort of let somebody rob $10 from a bank, but not $1,000.

Hartos - It was recognized that there are times when you need to fill in streams, for various activities, and that's under the 404 process. You're allowed to fill streams. There are certain things that need to be considered when you do that -- the biological wealth of the streams and other factors. The 404(b)(1) guidelines apply in those cases. It's a decision that needs to be made. An arbitrary "you can't do it anymore" . . . You wouldn't be able to do anything. **Hanmer** - Yes, of course you can if you get a 404 permit you can fill in wetlands. **Wallace** - You could fill in White Clay Creek! **Hanmer** - Mining is one of the most difficult activities to regulate, because it's geographically restricted -- in other words, the mineral resource sort of dictates where you're going to do something. Usually with bridges or highways or parking lots or floating crap games -- and we do a lot of filling to build floating crap games in Mississippi -- you try to argue that they don't have to put their casino on top of that wetland, or they don't have to put their hotel on top of that beach. That's part of the argument you have under 404(b)(1) -- Why do you have to do it there? Yes, the mining company has to show you they absolutely have to have that valley fill in order to exploit that resource. If they wind up showing you that they've gone as far as they can go on mitigation, then the burden of proof shifts back to society to say why is this water body so significant that it can't be sacrificed for this use. And states try to get ahead of that -- which West Virginia has not -- by trying to define "areas unsuitable for mining" based on some other system. But that's heavy going. Kentucky has unique biotic communities on Black Mountain, which is almost a test case in trying to set aside a large area and say "you cannot take this resource." And what you get back is "but there's a hundred million dollars worth of coal there!"

Stump - Maybe we should reorient our thoughts to the drainage area impacts vs. just the stream channel -- from here down I have a biological community. Looking at a type of mining focused on mountaintops, on filling first order streams. Maybe instead of focusing on the streams we should be focusing on amount of drainage area vs. stream channel. And if we're looking at a drainage area impacted by mining, and then a point of observation or evaluation downstream of that, and making decisions, vs. trying to determine where the stream starts and where the stream ends. Because I see that starting from the ridgetop and going on down, it's all a biological community, and vegetative community, all together and interrelated, so maybe we should be making our cutoffs more on a drainage area, or percentage of drainage area, of the total drainage area cutoff, in evaluations, and points of observation and jurisdiction. **Wallace** - I like Dennis' analogy -- Is it ok to steal $1, $10, or $100 or $1000 from a bank? When do you draw the limit? **Stump** - Well, in a regulatory framework we've got laws that mining is allowable with regulations, and we have to find that middle ground of

HOW MUCH CAN YOU IMPACT BEFORE YOU'RE NOT ALLOWED TO DO ADDITIONAL IMPACTS? WE'RE NOT IN A "PRESERVATIONIST" MODE, EXCEPT IN AREAS WHERE IT'S BEEN DETERMINED UNSUITABLE FOR MINING. **DENSMORE** - IT'S AN ENTITLEMENT PROGRAM.

HANMER - NO, I DON'T THINK IT IS. WE'RE TALKING ABOUT HOW CAN BIOLOGISTS BE THE MOST USEFUL? I THINK THERE ARE A LOT OF PEOPLE WHO ARE GOING TO SIT AROUND AT THE END OF THE DAY MAKING DECISIONS, ECONOMIC, POLITICAL, SOCIAL. BUT HOW IS THE BIOLOGIST'S VOICE BEST HEARD? HOW IS THE SCIENTIFIC INPUT THAT YOU HAVE TO MAKE TO THIS DECISION MAKING PROCESS BEST EXPRESSED? **UNKNOWN COMMENTER** - FOR WHAT PURPOSE? **HANMER** -- TO HELP US. MAYBE YOU'RE UPSET ABOUT THE WORD "VALUE." MAYBE IT'S ONLY PEOPLE LIKE US REGULATORS OR MINING COMPANIES WHO USE THE WORD VALUE AND THAT "VALUE" IS ACTUALLY AN ANATHEMA TYPE WORD TO YOU. FUNCTION -- USE FUNCTION, BUT TO HELP US TO ENRICH THE UNDERSTANDING OF THE FUNCTIONS, SO THAT PEOPLE KNOW THEY'RE GIVING UP SOMETHING, AND NOT NOTHING.

KINCAID - WE DO FILL VALLEYS, WE FILL FOURTH ORDER STREAMS. THE CORPS OF ENGINEERS HAS DONE A PRETTY GOOD JOB OF IT. THE DIFFERENCE IS THAT, UNDER THOSE CIRCUMSTANCES, USING TAXPAYER MONEY, WE HAVE TO DO A COMPLETE, DETAILED ENVIRONMENTAL ASSESSMENT. I DON'T THINK IT'S HAPPENING, BUT ARE WE TRYING TO SWEEP THE SENSITIVITY OF THESE HEADWATER AREAS AND THEIR IMPORTANCE UNDER THE TABLE, AT THE EXPENSE OF RUBBER-STAMPING AN EIS? I DON'T THINK WE SHOULD GET INTO THAT POSITION. WE NEED TO DO GOOD SCIENCE, DESIGN THE EXPERIMENTS, COLLECT THE DATA, AND INTERPRET IT, BUT AS PART OF THAT INTERPRETIVE PROCESS WE NEED TO INCLUDE THE UNIQUENESS OF THESE HEADWATER STREAMS.

HANDEL - I THINK IT'S INTERESTING THAT THE CORPS DOES SOMETIMES FILL FOURTH ORDER STREAMS. BUT RECENTLY, SOME OF THE CORPS' OLD ACTIONS ARE BEING REVERSED, AS NEW KNOWLEDGE AND PUBLIC SENTIMENT CHANGE. WHETHER IT'S PULLING OUT DAMS ON SALMON RIVERS OUT WEST TO THE REMARKABLE ACTION IN THE EVERGLADES, THIS IS ILLUMINATED BY NEW KNOWLEDGE AND NEW ATTITUDES. THIS GROUP IS CHARGED WITH DEVELOPING A MODERN UNDERSTANDING OF THESE LITTLE STREAMS TO SAY TO THE GOVERNMENT: "WELL, THESE THINGS REALLY DO HAVE TO BE SAVED, EVEN THOUGH 25 YEARS AGO WE SAID, LOOK THEY'RE TOO SMALL TO EVEN WORRY ABOUT, OTHER VALUES ARE MORE IMPORTANT. IS THIS PARTICULAR REGIONAL PROBLEM GOING TO BE LIKE THE EVERGLADES AND SALMON STREAMS IN OREGON? I'M JUST A BOTANIST, BUT IT SEEMS LIKE A PRETTY STRAIGHTFORWARD PROBLEM. ARE WE AT STATE WHERE WE SAY THE OLD LAWS WERE WELL-MEANING, OF COURSE, BUT WE HAVE TO MOVE ON FROM THERE.

NEWBOLD - THE SENTIMENT OF PROBABLY MOST OF THE PEOPLE IN THIS ROOM IS THAT THIS VALLEY FILLING IS A BAD IDEA, AND THAT THE WEIGHT OF THE SCIENTIFIC EVIDENCE -- THE IMPACT YOU COULD DOCUMENT, ALTHOUGH IT MIGHT BE A LOT OF PROBLEM TO DO IT -- WOULD MAKE A STRONG CASE AGAINST DOING IT AT ALL. YET THE REALITY SAYS WE CAN'T STOP IT. SO, WE HAVE TO STEP BACK AND TAKE A COMPROMISE APPROACH, IN WHICH INSTEAD OF DOCUMENTING WHY IT SHOULDN'T BE DONE AT ALL, WE ARE IN A POSITION OF DECIDING WHICH WATERSHEDS TO SACRIFICE AND HOW MANY, AND COMING UP WITH A SORT OF "CALCULUS" TO DO THAT. THAT CALCULUS IS WELL BEYOND THE FIRST STEP. WE ARE, AS SCIENTISTS, IN A POSITION TO BE ABLE TO SAY THIS HAS A STRONGLY NEGATIVE IMPACT, AND LIST THE IMPACTS, AND SAY THIS IS A PRACTICE THAT SHOULDN'T BE DONE. WE DON'T HAVE THE TECHNOLOGY TO CREATE A CALCULUS TO DECIDE WHAT PERCENT CAN BE DESTROYED. WHERE YOU DO SEE THIS KIND OF REGULATION DEVELOPED, WHERE THERE IS A CALCULUS, IT'S ALMOST ALWAYS A JOKE. IT TYPICALLY IS THE RESULT OF SOME KIND OF POLITICAL COMPROMISE, AND BECAUSE YOU COULDN'T REALLY DO IT RIGHT YOU HAD TO COME UP WITH SOME CRAZY SCHEME OF ADDING A LOT OF DIFFERING COEFFICIENTS TOGETHER OR WORKING THROUGH SOME KIND OF A MATRIX THAT EVERYONE REALIZES DOESN'T MAKE SENSE, BUT IT WAS COME UP WITH AS A COMPROMISE TO COME UP WITH A SLIDING SCALE WHICH ENDS UP IN MIDDLE GROUND.

HANMER - DO YOU REMEMBER LEOPOLD'S "UNIQUENESS INDEX" FROM 1972? MY CHALLENGE TO YOU IS THAT CHANGES OCCUR. THAT DEVELOPMENT OCCURS, AND THAT EVEN BIOLOGISTS LIVE IN HOUSES AND BENEFIT FROM DEVELOPMENT. SO THEN, THE QUESTION FOR US IS, DO YOU WANT THAT TO JUST HAPPEN HELTER-SKELTER, OR DO YOU WANT TO TRY TO FIGURE OUT AND TAKE SOME RESPONSIBILITY FOR IT? THAT'S THE DILEMMA YOU'RE IN. YOU'RE SAYING "I DON'T WANT TO TAKE RESPONSIBILITY SAYING THAT FILLING 10% OF THE HEADWATER STREAMS IS OK" AND I CAN UNDERSTAND WHY YOU WOULDN'T WANT THAT KIND OF RESPONSIBILITY. BUT UNFORTUNATELY, SOME OTHER PEOPLE HAVE TO TAKE THAT RESPONSIBILITY AND IT WOULD BE NICE IF THEY COULD DO IT ON THE BASIS OF THE BEST KIND OF INFORMATION THEY CAN GET.

WALLACE -THERE'S ANOTHER DANGER HERE, ESPECIALLY WHEN YOU CONSIDER LONG-TERM NITRIFICATION OF CATCHMENTS. THERE MIGHT BE THINGS HAPPENING HERE THAT WE'RE NOT GOING TO SEE UNTIL 15 OR 20 YEARS DOWN THE ROAD. ARE YOU GOING TO LET THESE PROCEED NOW, AND THEN FIND OUT 15 OR 20 YEARS LATER THAT THERE'S SOMETHING AWRY HERE THAT YOU CANNOT CORRECT? AND I'M PARTICULARLY THINKING ABOUT POTENTIAL FOR NITRATES IN THE SURFACE WATERS. THAT CAN BE PRETTY DANGEROUS. **KINCAID** - THAT'S ALL THE MORE REASON WHY WE NEED TO DESIGN GOOD EXPERIMENTS RIGHT NOW. **WALLACE** - EXACTLY, THAT'S WHAT I'M SAYING. AND THESE SHOULD BE MINIMIZED UNTIL WE SOLVE THE PROBLEM AND HAVE SOME IDEA OF THE WHAT KIND OF DOWNSTREAM EFFECTS THEY HAVE. **ROBINSON** - THERE ARE SOME VALLEY FILLS WHICH HAVE BEEN IN PLACE FOR 15 YEARS, CAN'T THESE BE STUDIED?

KINKAID - WE'RE TALKING ABOUT PROBLEMS THAT CAN COME TO GET US DECADES DOWN THE ROAD. WE NEED TO DESIGN THE EXPERIMENTS NOW PROJECTING THE PROBABLE IMPACTS, AND DETERMINING THE SIGNIFICANCE OF THE IMPACTS. I DON'T THINK RIGHT NOW, OR EVEN AFTER A YEAR'S WORTH OF DATA, WE'LL BE ABLE TO SORT OUT WHAT WE FIND FROM ENVIRONMENTAL NOISE WELL ENOUGH TO SAY THAT THESE IMPACTS ARE GOING TO OCCUR NEVER, TOMORROW, OR IN 2050. WE NEED TO BUILD INTO THE PROCESS SOME MEANS OF CONTINUING THIS EVALUATION PROCESS, AT THE SAME TIME THAT WE MEET THE DEADLINE.

DENSMORE - I WANTED TO BRING UP HERE, THAT GETS BACK TO THE SORT OF ARTIFICIAL CONSTRUCT WE GET INTO AS LAWYERS AND REGULATORS -- RIGHT NOW WE ARE LOOKING AT A 250-ACRE THRESHOLD FOR "MINIMAL" IMPACTS FOR PURPOSES OF THE PERMIT SYSTEM. THAT IS A NUMBER THAT HAS A LONG HISTORY, AND RELATES HISTORICALLY TO "AT WHAT POINT DO YOU REQUIRE COMPENSATION FOR LOSSES," BUT IT HAS NOW SORT OF JUMPED OVER AND BECOME A THRESHOLD BELOW WHICH YOU DON'T HAVE A SIGNIFICANT IMPACT ON THE SYSTEM. THIS HAS THE DANGER OF BECOMING LAW, THE WAY IT'S BEING USED RIGHT NOW, BECAUSE IT IS BEING USED AS A PRIMARY BASIS FOR PROCESSING CORPS OF ENGINEERS PERMITS.

WALLACE - THIS MEANS THAT ON ANY GIVEN DRAINAGE BASIN, YOU COULD FILL IN A SERIES OF FIRST AND SECOND ORDER STREAMS -- YOU COULD RAID THE BASIN, BASICALLY, AS FAR AS THE HEADWATERS -- EACH WITH SEPARATE FILLS OF UP TO 250 ACRES. **HANMER** - YOU COULD. **DENSMORE** - IT'S BEING SO RIGIDLY ADHERED TO THAT YOU COULD FILL 20 BASINS, SO LONG AS YOU KEPT THEM TO 249 ACRES OR LESS. I'D BE INTERESTED IN THE REACTION TO THAT HERE.

STAUFFER - DEPENDS WHICH 250 ACRES YOU'RE TALKING ABOUT. IF IT'S 249 ACRES OF WHITE CLAY CREEK WHERE THIS ONLY MAYFLY OCCURS, SOMEONE'S GOING TO HAVE A PROBLEM. IF IT'S THE 249 ACRES WHERE MY ONLY *PHOXINUS* OCCURS, I'M GOING TO HAVE A PROBLEM.

ROBINSON - IT'S NOT THAT SIMPLE, BECAUSE THERE'S A CAVEAT THAT SAYS THAT IF WE CONSIDER THAT MULTIPLE 250 ACRES BECOME CUMULATIVELY SIGNIFICANT -- AND WE HAVE TO KNOW WHAT THAT MEANS. SO, HOW MANY 250'S DO WE DO BEFORE ... **HOFFMAN** - OR, THE 249 ON YOUR SENSITIVE CREEK IS SENSITIVE. **ROBINSON** - OR THERE'S A THREATENED OR ENDANGERED SPECIES OR A WETLAND OR A FEDERAL TRUST RESOURCE.

STAUFFER - SOMEBODY MIGHT NOT WANT TO WIPE OUT A SONGBIRD, SOMEBODY MIGHT NOT WANT TO WIPE OUT A SALAMANDER, AND SOMEBODY ELSE WANTS TO PROTECT A FISH, WANT TO PROTECT A MAYFLY, THEN THE DINOFLAGELLATE AND A BACTERIA, AND YOU'VE GOT A QUALITY JUDGEMENT THERE. I'M PRETTY SURE THAT ALL OF THESE SYSTEMS HAVE SOME UNIQUE ORGANISMS AT SOME LEVEL OR ANOTHER ASSOCIATED WITH THEM. **ROBINSON** - AND AS REGULATORS, WE LOOK FOR BLACK AND WHITE LINES, AND WE KEEP PUSHING PEOPLE TO TELL US WHERE THEY ARE, AND IT DEPENDS ON YOUR INTEREST AND WHAT PART OF SCIENCE YOU COME FROM AS TO WHAT YOU CARE ABOUT. **STAUFFER** - IT GETS BACK TO THE $10 OR $1,000: "I'M WILLING TO GIVE UP A FISH BUT NOT A SONGBIRD," OR "I'M WILLING TO GIVE UP A MAYFLY BUT NOT A FISH."

TIBBOTT - WE'VE TRANSITIONED TO OUR NEXT QUESTION: HOW MUCH CAN WE GIVE UP? HOW MUCH CAN WE AFFORD TO LOSE? THERE ARE 40 PERMITS THAT HAVE TO BE DEALT WITH. SIX OF THE 40 HAVE MULTIPLE FILLS UNDER 250 ACRES. THE FISH AND WILDLIFE SERVICE IS THE ONLY AGENCY AMONG THE FIVE AGENCIES THAT CONSIDERS THIS A SIGNIFICANT CUMULATIVE IMPACT; ALL THE OTHER AGENCIES WOULD JUST AS SOON LET THEM GO AS NATIONWIDE

PERMIT AUTHORIZATION. THE FISH AND WILDLIFE SERVICE IS INTERESTED IN YOUR REACTION TO WHAT DO WE DO WITH MULTIPLE FILLS?

ARWAY - JUST A COMMENT ABOUT CUMULATIVE IMPACTS. THERE'S A PROVISION IN SMCRA THAT DEALS WITH CUMULATIVE HYDROLOGIC IMPACT ASSESSMENTS. WHERE STATES HAVE DELEGATED PROGRAMS, THEY HAVE TO DO CHIAS. TO MY KNOWLEDGE, NO PERMIT HAS EVER BEEN DENIED OR ALTERED BECAUSE OF CHIAS. WE'VE BEEN DOING CHIAS FOR A LONG TIME, BUT I'VE NEVER SEEN ANY EFFECT ON THE PERMIT PROCESS. **TIBBOTT** - I DON'T THINK THEY'VE REALLY BEEN DONE. **ARWAY** - THE OBLIGATION OF THE AUTHORITY IS THERE, AND THE STATE HAS TO "CHECK THE BLOCK" WHEN IT ISSUES THE PERMIT THAT THE CHIA HAS BEEN DONE. **TIBBOTT** - ALTHOUGH THE BLOCK IS CHECKED, THEY'RE NOT DONE. **ARWAY** - WELL, THEY'RE REQUIRED TO BE DONE AND IN THEORY THEY ARE DONE. HISTORY TEACHES US THAT THEY'RE REQUIRED TO BE DONE, BUT THEY'RE NOT DONE, AND PERMITS ARE STILL ISSUED.

NEWBOLD - CAN WE GO DOWNSTREAM AND IDENTIFY THE RESOURCES ON WHICH THE CUMULATIVE IMPACTS MIGHT BE FELT; A SPECIFIC REACH OF STREAM, A LAKE, AN ESTUARY IF YOU GET FAR ENOUGH DOWN? IS THAT A USEFUL WAY OF LOOKING AT THE QUESTION? **ROBINSON** - IT GOES BACK TO WHAT ARE THE VALUES THAT YOU ASSESS, AT WHICH CUMULATIVE PROBLEMS START KICKING IN. **NEWBOLD** - IF WE GET IN A BOAT AND GO DOWNSTREAM, AND WE COME TO THIS STRETCH OF RIVER THAT'S USED FOR FISHING OR WHITEWATER RAFTING, OR COME TO A LAKE THAT HAS A FISHERY, THEN WE SEE THE RESOURCES AND WE SAY ARE THESE AT RISK OF BEING IMPACTED, SO INSTEAD OF WORKING FROM, "WELL, WE COULD HAVE ALL THESE KINDS OF IMPACTS DOWNSTREAM," AND WORKING THROUGH THAT, WE GO DOWNSTREAM AND SEE WHAT MIGHT BE VULNERABLE AND WHAT MIGHT BE THE IMPACTS. **ROBINSON** - REGULATORS STRUGGLE WITH "HOW FAR DOWNSTREAM" YOU'RE SUPPOSED TO DEFINE CUMULATIVE IMPACT AREAS. IS IT THE GULF OF MEXICO OR THE CLINCH RIVER OR THE CHEAT RIVER OR SOME TRIBUTARY OF THE CHEAT RIVER. **COMMENTER** - THE GULF OF MEXICO IS A CANDIDATE BECAUSE THERE ARE NUTRIENT PROBLEMS IN THE GULF OF MEXICO IN REGARDS TO NITRATES. **ROBINSON** - IF YOU CHOOSE THE GULF OF MEXICO AND WE HAVE TO LOOK AT WATER QUANTITY AND QUALITY AND WELLS AND THINGS, THE POOR CITIZEN WHOSE WELL IS IMPACTED BY UNDERGROUND MINING OR SURFACE MINING, IF YOU'RE LOOKING AT THE GULF OF MEXICO THAT BECOMES AN INSIGNIFICANT IMPACT AND SO YOU CAN WRITE IT OFF. SO WHERE YOU DRAW THE LINE SO YOU CAN EVALUATE IMPACTS IS SOMETHING THAT HAS TO BE DECIDED.

A Review of Wetland Resources in the Steep Slope Terrain of West Virginia

November 8, 2000

Prepared For:

Mountaintop Mining/Valley Fill
Programmatic Environmental Impact
Statement

Prepared by:

David Rider
William Hoffman
USEPA Region 3
Philadelphia, PA

A Review of Wetland Resources in the Steep Slope Terrain of West Virginia

Introduction

Wetland resources can be of significant importance in protecting and improving water quality. They can filter pollutants from the water column, provide habitat, and provide a food source for many aquatic, avian, and terrestrial species. Wetlands can also provide significant sediment trapping and flood control benefits.

A typical mountaintop mining/valley fill (MTM/VF) operation in the Appalachian coalfields removes overburden and interburden material to facilitate the extraction of low-sulfur coal seams, and has often required the placement of excess spoil into valleys containing first and second order streams. While it is likely that few wetland resources exist naturally in the steep slope terrain areas because of the topography, the actual impacts of MTM/VF operations on these resources is largely unknown. Moreover, during scoping sessions and technical symposia held for the Mountaintop Mining/Valley Fill Programmatic Environmental Impact Statement, it was reported by industry representatives that new wetland communities are becoming established at reclaimed mine sites, often within sediment retaining structures or in other basin areas on the mined sites. The extent of these areas or the functions they are providing, however, is also uncertain.

To evaluate these issues, a workplan was developed to assess the prevalence and functions of wetland resources in the steep slope mining region. This workplan can be seen on EPA's mountaintop mining web site at www.epa.gov/region3/mtntop.

Approach

To assess the degree to which wetland resources exist in the steep slope area, National Wetland Inventory (NWI) maps were reviewed for the same five watersheds being evaluated under workplans developed by the Stream and Fisheries Teams for the EIS (Twentymile Creek, Spruce Fork, Mud River, Island Creek, and Clear Fork). NWI maps were developed by the U.S. Fish and Wildlife Service to identify natural and/or manmade wetland systems in existence at the time of mapping, and can be used as a screening tool to assess the relative percent of wetlands in the landscape.

To assess wetland functions typically found on reclaimed mine sites, a field team performed functional assessments (water quality, wildlife, and sediment trapping) on November 16-17, 1999 at ten wetland sites suggested by coal companies. The Evaluation of Planned Wetlands (EPW) technique, a rapid-assessment procedure developed by Environmental Concern, Inc., was utilized to perform these field assessments. Three EPW functions were selected:

- Sediment Stabilization- Capacity to stabilize and retain previously deposited sediments.
- Water Quality- Capacity to retain and process dissolved or particulate materials to the

benefit of downstream surface water quality.

- Wildlife- Degree to which a wetland functions as habitat for wildlife as described by habitat complexity.

The functional capacity is determined by comparing elements of physical, chemical, or biological characteristics that demonstrate the wetland's capacity to perform a function. The element score is a unitless number from 0.0 to 1.0, where 1.0 represents the optimal condition for maximizing functional capacity and 0.0 represents an unsuitable condition. A high score implies that, in comparison to the other conditions for that element, this particular condition has a greater potential to increase the wetland's functional capacity. Conversely, a low score implies that there is a low potential.

Results

As can be seen from the National Wetland Inventory maps (Attachment 1), the percentage of vegetated wetlands (PF, PEM, PSS designations) existing in these watersheds is extremely low, representing less than 1/10 of 1% of the watershed in all cases. The majority of the NWI wetlands in these watersheds, furthermore, are unvegetated wetlands, and appear in most cases to be sediment ponds (PUB designations) associated with mined sites. Unvegetated wetlands also represent a very low percentage of the landscape in these five watersheds.

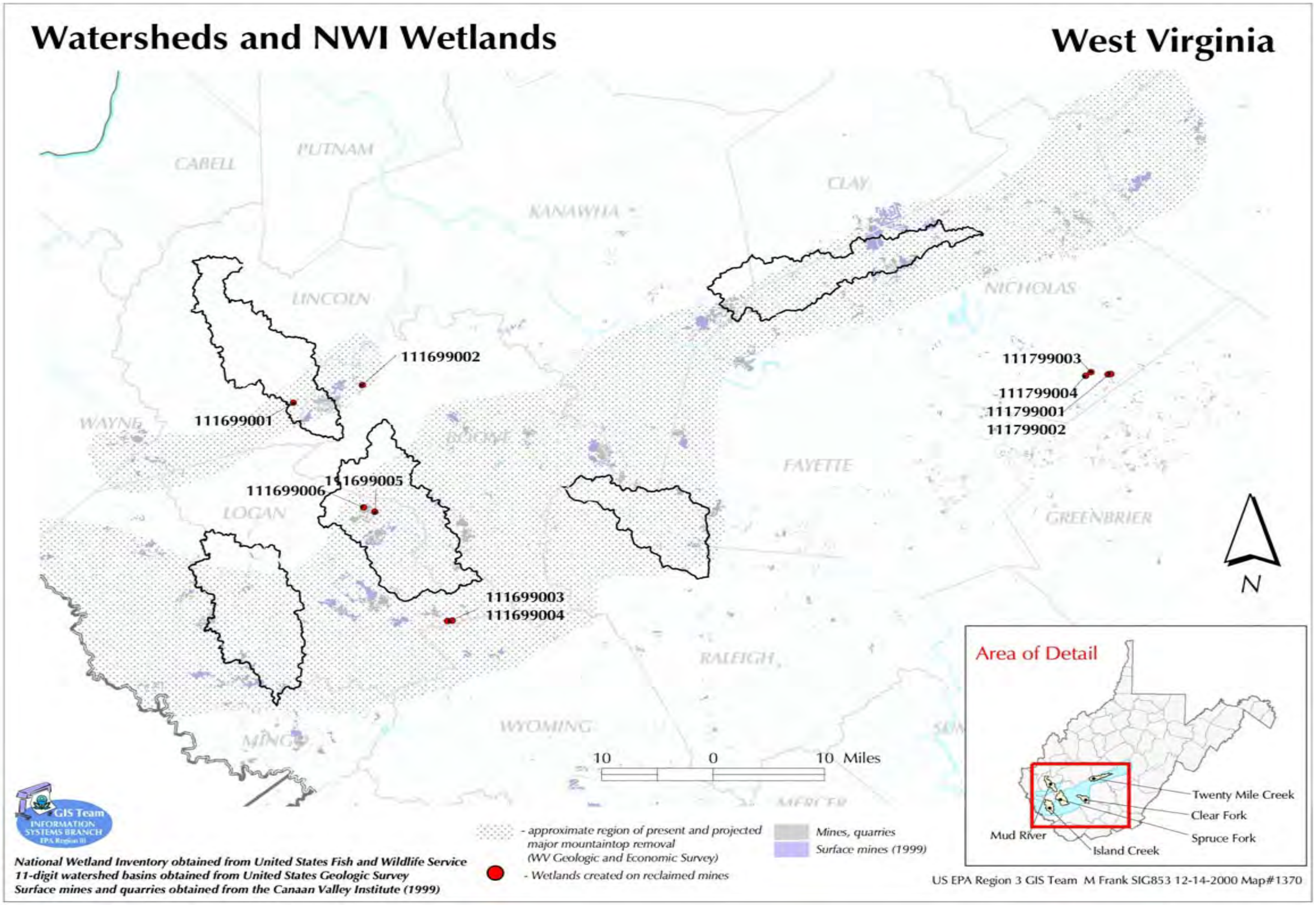
As can be seen from the results of the functional assessments performed at ten wetlands sites located on reclaimed areas (Attachment 2), most of the sites functioned well as sediment retention devices. Three of the ten sites scored a maximum of 1.0 and another three sites had scores equal to or greater than 0.7. Wetlands at these sites had established persistent vegetation that could trap and hold sediment. Only two of the ten sites (111699003 and 111799004) had a high rating for the water quality function to retain and process dissolved or particulate materials to the benefit of downstream surface water quality. At one site (111699003), this high rating appeared to be as a result of sheet flow though persistent vegetation established on relatively fine mineral soils. Another site (111799004) that ranked high for water quality was established on a high-wall bench left from the pre-SMCRA mining period. Here, persistent wetland vegetation was established on a broad area of side-slope seeps, probably without any intention to collect water or provide sediment retention. Two sites rated highly for the wildlife function. One site (111799003) was found on an older (20+ years) area and was characterized by a shallow pond against a railroad crossing. Tree snags and a variety of vegetation layers characterized this old sediment basin. The wildlife functional index provides a relative measure of the degree to which a wetland functions as habitat for wildlife as described by habitat complexity. Disturbances from past mining activities at this site were minimal and a wide range of cover types was evident. Wildlife functions were low at most sites due to a lack of wildlife attractors such as snags, dense brush, and fallen trees or logs. Multiple vegetation layers were not common.

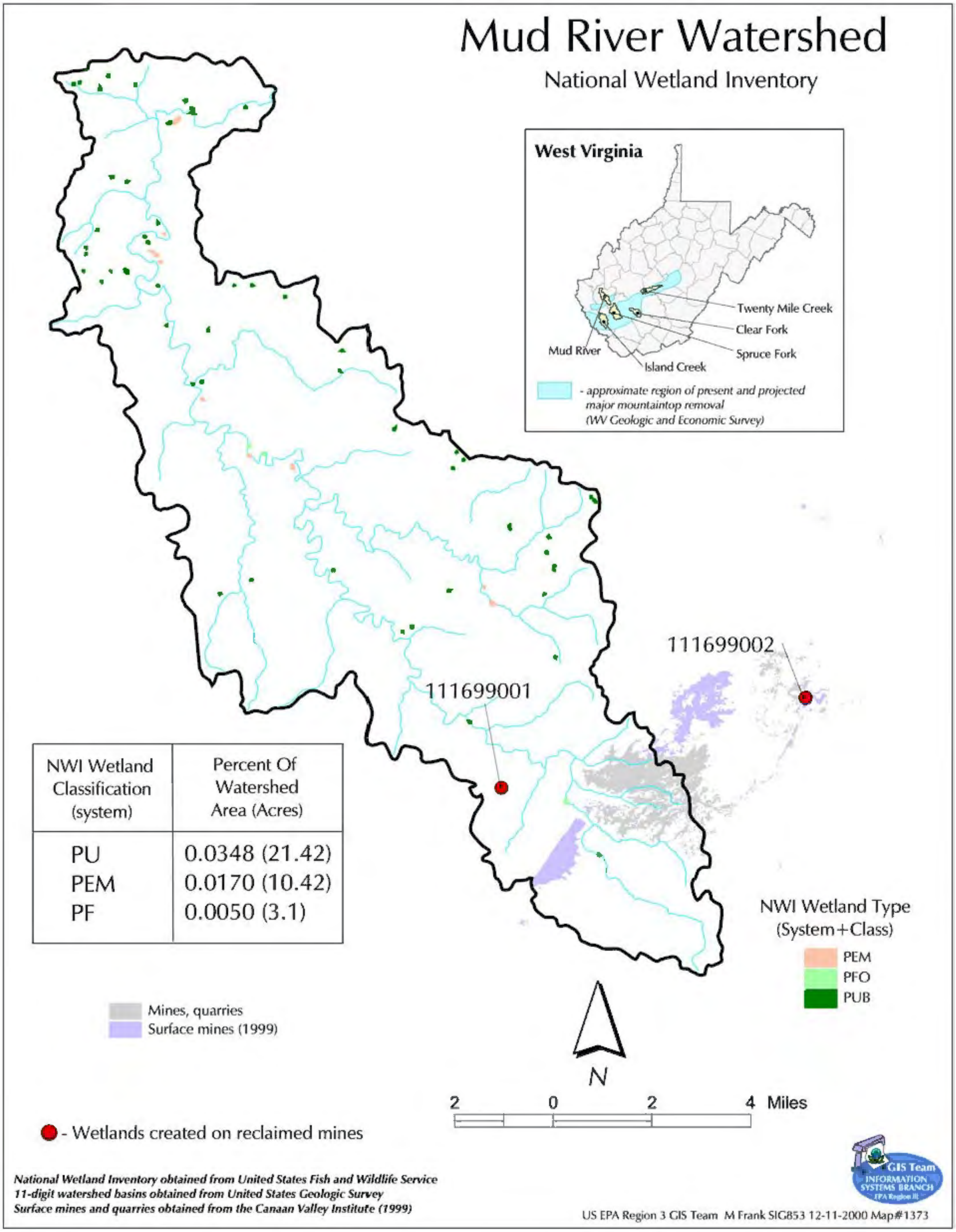
Discussion

Wetland resources do not seem to be a major landcover type in the steep slope terrain of West Virginia. The predominate class, further, appears to be unvegetated ponds associated with mined sites. Vegetated wetland areas that do exist, even on mined sites, are generally small areas scattered throughout the landscape.

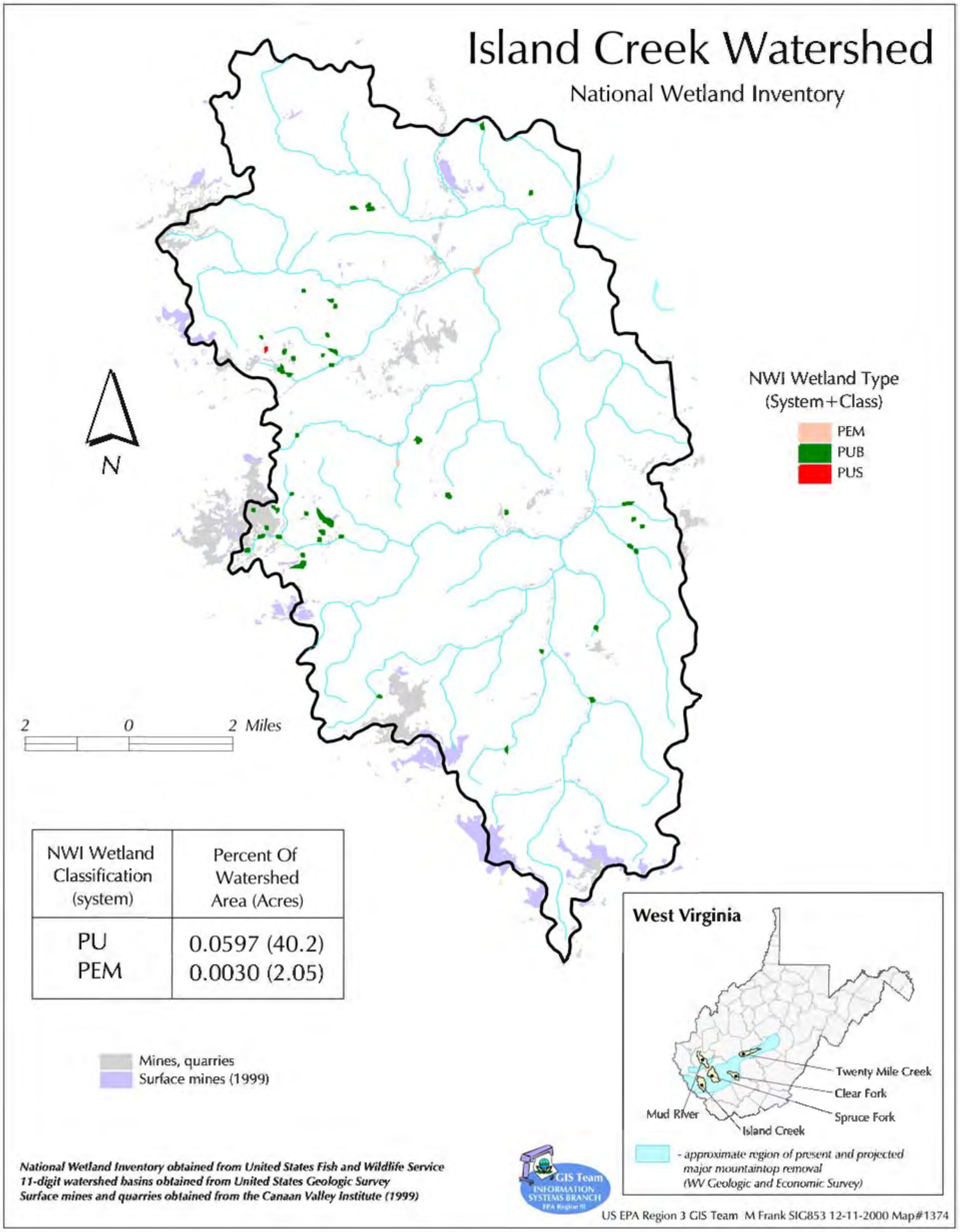
At the ten wetland sites studied (mainly linear drainage structures and basin depressions) on mined areas, the functions being provided varied. Many of the wetland systems were providing excellent sediment stabilization functions, and a few were providing good water quality (as defined in EPW technique) and wildlife functions. These findings were not unexpected by the field team conducting the survey. As these structures were designed to control sediment, we expected them to score highly in this regard. The defined water quality function, on the other hand, is very much dependent on vegetative cover within the wetland system, and the low percentage of vegetative cover at these sites appeared to be the reason for their low scores in this regard. Wildlife scores are also highly dependent on the vegetative communities present, the degree of interspersion, and other physical and biological features of the system. Because these sites were not designed for these purposes, it is not surprising that they did not score highly. The areas that did score highly tended to be older systems where more complex structures were permitted to develop. The conclusion is that although many of the sites evaluated did not score highly for various wetland functions and values, opportunities do appear to exist for the creation of functioning wetland systems on mined sites. Planned wetlands, if incorporated into the restoration design, can provide valuable functions by enhancing sediment stabilization, water quality improvement, and wildlife habitat on mined sites.

ATTACHMENT 1

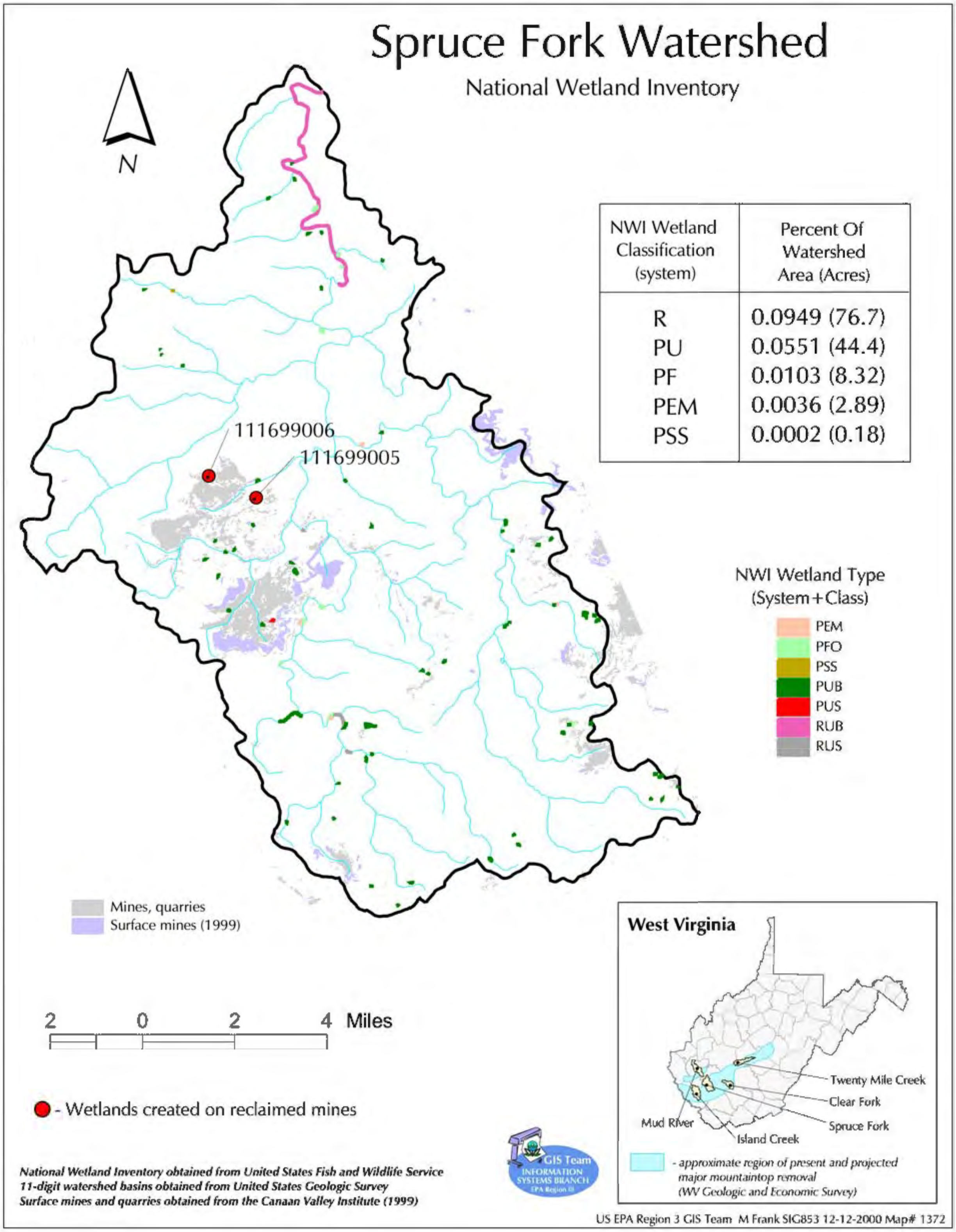




NWI Wetland Classification (system)	Percent Of Watershed Area (Acres)
PU	0.0348 (21.42)
PEM	0.0170 (10.42)
PF	0.0050 (3.1)

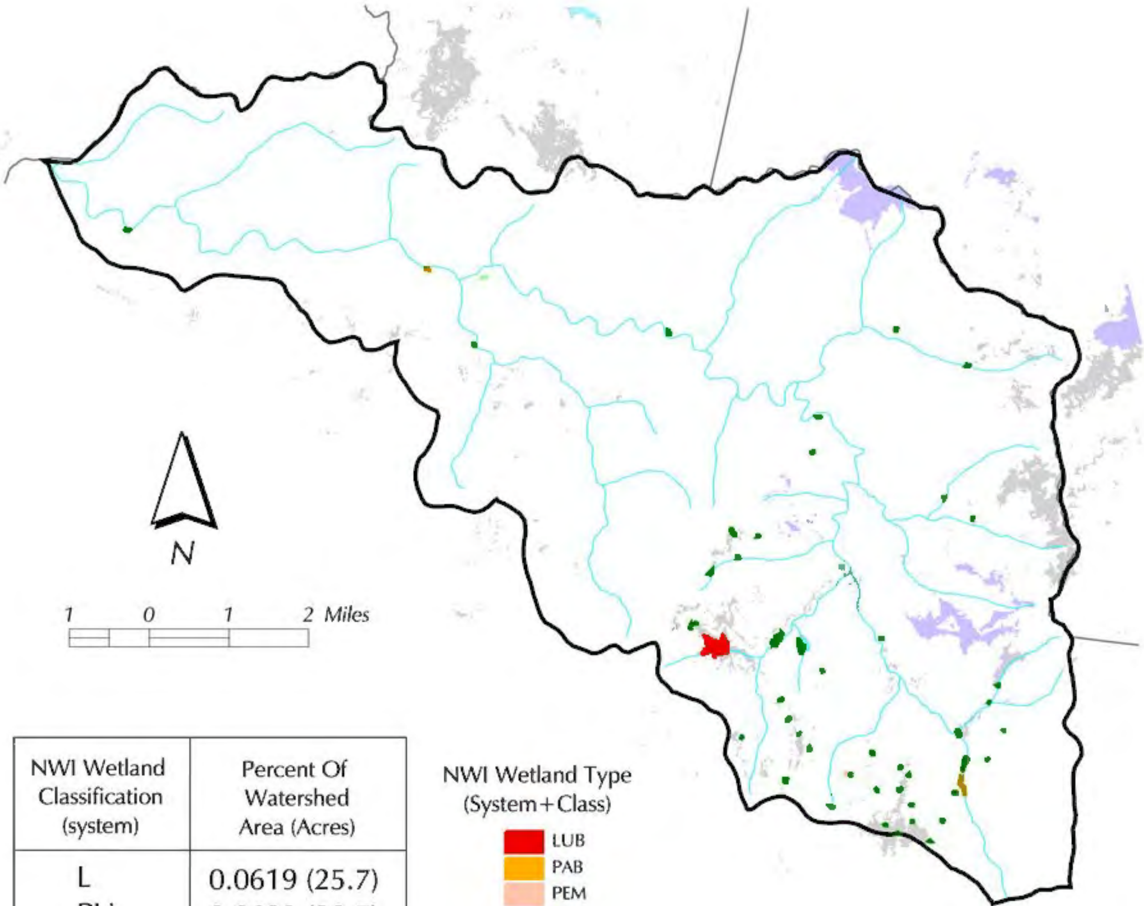


NWI Wetland Classification (system)	Percent Of Watershed Area (Acres)
PU	0.0597 (40.2)
PEM	0.0030 (2.05)


Spruce Fork Watershed
National Wetland Inventory
N
NWI Wetland Classification (system)
Percent Of Watershed Area (Acres)
R 0.0949 (76.7)
PU 0.0551 (44.4)
PF 0.0103 (8.32)
PEM 0.0036 (2.89)
PSS 0.0002 (0.18)
111699006
111699005
NWI Wetland Type (System+Class)
PEM
PFO
PSS
PUB
PUS
RUB
RUS
Mines, quarries
Surface mines (1999)
2 0 2 4 Miles
- Wetlands created on reclaimed mines
West Virginia
Twenty Mile Creek
Clear Fork
Spruce Fork
Mud River
Island Creek
- approximate region of present and projected major mountaintop removal (WV Geologic and Economic Survey)
National Wetland Inventory obtained from United States Fish and Wildlife Service
11-digit watershed basins obtained from United States Geologic Survey
Surface mines and quarries obtained from the Canaan Valley Institute (1999)
GIS Team
INFORMATION SYSTEMS BRANCH
US EPA Region 3 GIS Team M Frank SIG853 12-12-2000 Map# 1372

Clear Fork Watershed

National Wetland Inventory

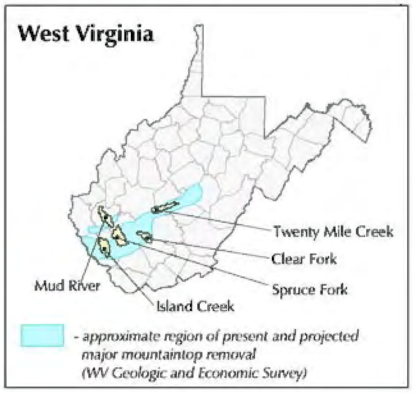


NWI Wetland Classification (system)	Percent Of Watershed Area (Acres)
L	0.0619 (25.7)
PU	0.0693 (28.7)
PSS	0.0087 (3.6)
PF	0.0012 (0.50)
PEM	0.0006 (0.26)
PA	0.0007 (0.30)

NWI Wetland Type (System+Class)

- LUB
- PAB
- PEM
- PFO
- PSS
- PUB

- Mines, quarries
- Surface mines (1999)



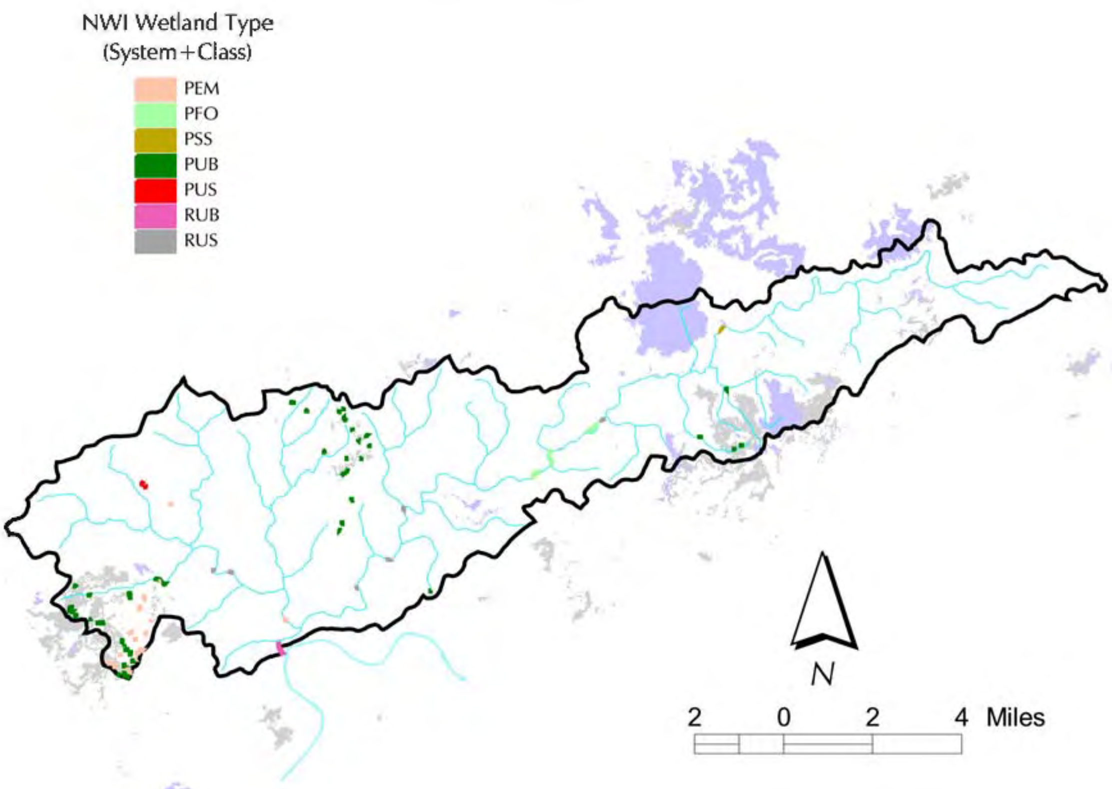
National Wetland Inventory obtained from United States Fish and Wildlife Service
11-digit watershed basins obtained from United States Geologic Survey
Surface mines and quarries obtained from the Canaan Valley Institute (1999)

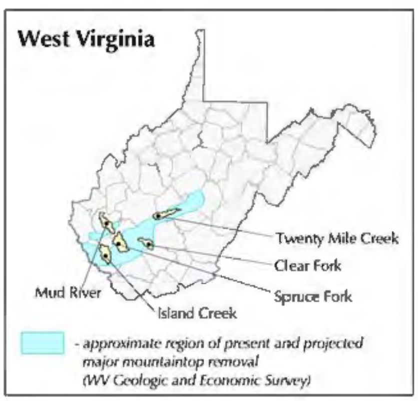
GIS Team INFORMATION SYSTEMS BRANCH EPA Region III

US EPA Region 3 GIS Team M Frank SIG853 12-13-2000 Map#1375

Twenty Mile Creek Watershed

National Wetland Inventory





Mines, quarries
Surface mines (1999)

NWI Wetland Classification (system)	Percent Of Watershed Area (Acres)
PU	0.0480 (26.47)
PF	0.0221 (12.3)
PEM	0.0152 (8.42)
R	0.0152 (8.40)
PSS	0.0010 (0.57)

National Wetland Inventory obtained from United States Fish and Wildlife Service
11-digit watershed basins obtained from United States Geologic Survey
Surface mines and quarries obtained from the Canaan Valley Institute (1999)

US EPA Region 3 GIS Team M Frank SIG853 12-12-2000 Map#1371

ATTACHMENT 2

ID #	**Sediment Stabilization**	**Water Quality**	**Wildlife**	**Description**	**Location**
111699001	0.70	0.50	0.34	Hobet 21, left Fork of Stanley Fork S 5080-88 5,400' long x 14' long sediment ditch	N38 04.987 W81 59.091
111699002	1.00	NA	0.25	Hobet 21 - isolated basin	N38 06.736 W81 52.379
111699003	1.00	0.97	0.13	Wylo Mine Complex - Pond F; 20 years old Discharge to Buffalo Creek sediment control - 800' x 50' S0159-74	N37 46.199 W81 43.212
111699004	1.00	NA	0.23	Wylo - Depressional wetland not a drainage structure no outlet exists 5-10 acres	N37 46.238 W81 42.730
111699005	0.53	NA	0.42	Dal-Tex - Rockhouse Robinson Run Pond	N37 55.638 W81 50.673
111699006	0.87	0.61	0.50	Dal-Tex - Sediment Ditches (w/check dams) pater-noster pond ~9 acres	N37 56.017 W81 51.812
111799001	0.08	0.22	0.38	Sediment ditches drain from 2 directions to underground mine - Pre-law -Beaver S3068-88 Green Valley Coal Co.	N38 09.112 W80 38.759
111799002	0.53	0.39	0.85	with snags ponds at foot of surface mine	N38 09.150 W80 38.494
111799003	0.78	0.68	0.81	Upper Brushy Meadow Sediment	N38 09.274 W80 40.467
111799004	0.27	0.98	0.68	side-slope seeps to bench S3075-87	N38 08.935 W80 40.982