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

October 2005

Introduction, Comment Summaries, Responses, and Errata

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

This Final Programmatic Environmental Impact Statement (FPEIS) has been prepared by the lead agencies listed below pursuant to the Settlement Agreement entered in Bragg v. Robertson, Civ. No. 2:98-0636 (S.D. W.V.). That Agreement provided for the preparation of the EIS, but the agencies did not concede that the EIS was required by the National Environmental Policy Act (NEPA). This Final EIS is "programmatic" in that it considers "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 affected by mountaintop mining operations, and to environmental resources that could be affected by the size and location of excess spoil disposal sites in valley fills" within the Appalachian study area in West Virginia, Kentucky, Virginia, and Tennessee. The objective is consonant application of the Clean Water Act and the Surface Mining Control and Reclamation Act to improve the regulatory process and effect better environmental protection for mountaintop mining and valley fill operations in steep slope Appalachia.

This FPEIS was prepared in accordance with the provision set forth in 40 CFR 1503.4(c) of the regulations implementing NEPA, which allow the agencies to attach an errata sheet to the statement instead of rewriting the draft statement and to circulate the errata, comments, responses, and the changes, rather than the entire document. The agencies are filing the entire statement with a new cover sheet as the final. The Draft PEIS and Final PEIS with comments, responses, and errata are available on the internet at the following address:

http://www.epa.gov/region3/mtntop/index.htm

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1. Summary

1.1 Introduction

This Final Programmatic Environmental Impact Statement (FPEIS) was prepared by the U.S. Army Corps of Engineers (COE), the U.S. Environmental Protection Agency (EPA), the U.S. Department of Interior's Office of Surface Mining (OSM) and Fish and Wildlife Service (FWS), and the West Virginia Department of Environmental Protection (WVDEP) ("the agencies") as part of a settlement agreement that resolved the Federal claims of the coal mining court case known as *Bragg v. Robertson, Civ. No. 2:98-0636 (S.D. W.V.).* That Agreement provided for the preparation of the PEIS, but the agencies did not concede that the PEIS was required by the National Environmental Policy Act (NEPA).

The purpose of this FPEIS is to evaluate options for improving agency programs under the Clean Water Act (CWA), Surface Mining Control and Reclamation Act (SMCRA) and the Endangered Species Act (ESA) that will contribute to reducing the adverse environmental impacts of mountaintop mining operations and excess spoil valley fills (MTM/VF) in Appalachia. Preparation of this FPEIS involved substantial information gathering, and it describes relevant historical data, details several possible alternative frameworks, and contains the results of over 30 scientific and technical studies conducted as a part of this effort.

The agencies identified a preferred alternative that incorporates programmatic improvements at the state and Federal levels intended to provide enhanced environmental protection and agency coordination during permit reviews under SMCRA and CWA consistent with the purpose of the PEIS as outlined below in Section 1.2 of this document. The preferred alternative enhances environmental protection and improves efficiency, collaboration, division of labor, benefits to the public and applicants. See Section II.B for a more detailed description of the benefits of the preferred alternative.

This FPEIS, was developed through an extraordinary inter-agency effort, and is designed to inform more environmentally sound decision-making for future permitting of MTM/VF. To this end, this FPEIS includes a substantial amount of environmental and economic data associated with MTM/VF collected and analyzed by these agencies. They have cooperatively evaluated their various programs and believe this FPEIS includes much valuable information that will assist their respective agencies to better coordinate the review necessary under each agency's mandates. The agencies believe this effort will contribute to more efficient decision-making by coordinating data collection and environmental analyses by the respective agencies, resulting in better permit decisions on a watershed basis.

This FPEIS includes the following: the comments received on the DPEIS (only one copy of each form letter where multiple copies were received); issues identified in the comments; responses on the issues; and an errata sheet. The FPEIS incorporates by reference the DPEIS published in June 2003. After considering all the comments received on the DPEIS and responding, the agencies have determined that the changes required to the DPEIS are minor. Therefore, the agencies are implementing the provision of the Council on Environmental Quality

(CEQ) regulations for implementing National Environmental Policy Act (NEPA), at section 1503.4(c), which reads:

> (c) If changes in response to comments are minor and are confined to the responses described in paragraphs (a)(4) and (5) of this section, agencies may write them on errata sheets and attach them to the statement instead of rewriting the draft statement. In such cases only the comments, the responses, and the changes and not the final statement need be circulated (Sec. 1502.19). The entire document with a new cover sheet shall be filed as the final statement (Sec. 1506.9).

In accordance with this provision, the agencies will be placing a FPEIS cover sheet on the DPEIS and, along with the errata sheet and comments/responses, filing it with the EPA as the FPEIS. Only this document, which includes comments, responses, and errata will be circulated to the public; the DPEIS was previously circulated to the public. The DPEIS is still available on the Internet at the following web address: http://www.epa.gov/region3/mtntop/index.htm. Hard copies are no longer available. However, libraries that received CDs of the DPEIS as listed in the distribution list of the DPEIS may still have those available. Computer disks containing the DPEIS can be obtained by writing the U.S. EPA.

1.2 Origin, Background, and Scope

On February 5, 1999, the COE, EPA, OSM, FWS, and WVDEP published a Notice of Intent in the Federal Register [64 FR5778] to develop an EIS with the following stated purpose:

> "…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 affected by mountaintop mining operations, and to environmental resources that could be affected by the size and location of excess spoil disposal sites in valley fills."

This is a "programmatic" EIS consistent with NEPA in that it evaluates broad Federal actions such as the adoption of new or revised agency program guidance, policies, or regulations. "Mountaintop mining" refers to coal mining by surface methods (e.g., contour mining, area mining, and mountaintop removal mining) in the steep terrain of the central Appalachian coalfields. The additional volume of broken rock that is often generated as a result of this mining, but cannot be returned to the locations from which it was removed, is known as "excess spoil" and is typically placed in valleys adjacent to the surface mine, resulting in "valley fills." Background on the NEPA process, issues analyzed as part of this PEIS, and relevant historical information can be found in Chapter I.

The geographic focus of this study involves approximately 12 million acres, encompassing most of eastern Kentucky, southern West Virginia, western Virginia, and scattered areas of eastern Tennessee. The study area contains about 59,000 miles of streams. Some of the streams flow all year, some flow part of the year, and some flow only briefly after a rainstorm or snow melt. Most of the streams discussed in this PEIS are considered headwater streams. Headwater streams are generally important ecologically because they contain not only diverse invertebrate assemblages, but some unique aquatic species. Headwater streams also provide organic energy that is critical to fish and other aquatic species throughout an entire river. Ecologically, the study area is valuable because of its rich plant life and because it is a suitable habitat for diverse populations of migratory songbirds, mammals, and amphibians. The environment affected by MTM/VF is described in Chapter III.

The U.S. Department of Energy (DOE) estimated in 1998 that 28.5 billion tons of high quality coal (i.e., high heating value, low sulfur content) remain in the study area. DOE reported about 280 million tons of coal were extracted by surface and underground mining from the study area in 1998. Coal produced from the study area continues to provide an important part of the energy needs of the nation. Regionally, coal mining is a key component of the economy providing jobs and tax revenue. Almost all of the electricity generated in the area comes from coal-fired power plants. Although coal production remains high, productivity gains and new technology have reduced the need for coal miners. Unemployment, poverty, and out migration in the study area are well above the national average. Mining methods, demographics and economics are also discussed in Chapter III.

The Surface Mining Control and Reclamation Act (SMCRA) was enacted by Congress in 1977 to provide a comprehensive program to regulate surface coal mining and reclamation operations, including MTM/VF. A variety of Clean Water Act (CWA) programs apply to MTM/VF activities where these activities may impact the chemical, physical, and biological integrity of the nation's waters. Section 404 of the CWA regulates the discharge of dredged or fill material into waters of the U.S. Section 402 regulates all other point source discharges of pollutants into waters of the U.S. Technology based effluent limits for the NPDES program are established by EPA to restrict the concentration of particular pollutants associated with a particular industry (e.g., iron for coal mining discharges). Section 401 provides states with the authority to review and either deny or grant certification for any activities requiring a Federal permit or license, to ensure that they will not violate applicable state water quality standards. CWA and SMCRA regulatory agencies must either consult or coordinate with the FWS, as appropriate to ensure the protection of endangered and threatened species and their critical habitats as determined under the Endangered Species Act (ESA). Relevant features of the SMCRA, CWA, ESA, and Clean Air Act (CAA) programs are discussed throughout the document, but are described in some detail under the No Action Alternative in Chapter II and in Appendix B. Chapter II and Appendix B are provided only as a brief informal summary for the convenience of the reader. These descriptions are not intended as a complete statement of applicable law or to establish the actual requirements of any regulatory program. The reader should refer to the statutes and the Federal Register for official program requirements.

1.3 Technical Studies

The agencies conducted or funded over 30 studies of the impacts of mountaintop mining and associated excess spoil disposal valley fills. The findings of these studies, along with the joint agency review of the existing regulatory environment, form the basis upon which the significance of each issue was evaluated. The results of these studies, compilation of previously published research, and information from various experts regarding the effects of mountaintop mining are in the appendices or are cited in the reference sections.

Individuals and agencies outside of the PEIS development process conducted some studies. The studies were summarized at the beginning of the applicable appendices. These appendix cover sheets are provided as an aid to the reader and do not necessarily reflect the opinions and views of the PEIS agencies. The studies noted the following:

- Of the largely forested study area, approximately 6.8 % has been or may be affected by recent and future (1992-2012) mountaintop mining [USEPA, 2002]. In the past, reclamation focused primarily on erosion prevention and backfill stability and not reclamation with trees. Compacted backfill material hindered tree establishment and growth; reclaimed soils were more conducive for growing grass; and grasses, which out-competed tree seedlings, were often planted as a quick growing vegetative cover. As a result, natural succession by trees and woody plants on reclaimed mined land (with intended post-mining land uses other than forest) was slowed. Better reclamation techniques for growing trees on mined lands now exist and are being promoted.
- More species of interior forest songbirds occur in forest unaffected by mining than forest edge adjacent to reclaimed mined land. Grassland bird species are more predominant on reclaimed mines. Similarly, amphibians (salamanders) dominate unaffected forest, whereas reptiles (snakes) occupy the reclaimed mined lands. Small mammals and raptors appear to inhabit both habitats.
- Approximately 1200 miles of headwater streams (or 2% of the streams in the study area) were directly impacted by MTM/VF features including coal removal areas, valley fills, roads, and ponds between 1992 and 2002. An estimated 724 stream miles (1.2 % of streams) were covered by valley fills from 1985 to 2001. Certain watersheds were more impacted by MTM/VF than others.
- Based upon the study of 37 stream segments, intermittent streams and perennial streams begin in very small watersheds, with a median of 14 and 41 acres respectively.
- Streams in watersheds where MTM/VFs exist are characterized by an increase of minerals in the water as well as less diverse and more pollutant-tolerant macroinvertebrates and fish species. Questions still remain regarding the correlation of impacts to the age, size, and number of valley fills in a watershed, and effects on genetic diversity. Some streams below fills showed biological assemblages and water quality of good quality comparable to reference streams.
- Streams in watersheds below valley fills tend to have greater base flow. These flows are more persistent than comparable unmined watersheds. Streams with fills generally have lower peak discharges than unmined watersheds during most low-intensity storm events; however, this phenomenon appears to reverse itself during higher-intensity events.

- Wetlands are, at times inadvertently and other times intentionally, created by mining via erosion and sediment control structures. These wetlands provide some aquatic functions, but are generally not of high quality.
- Valley fills are generally stable, as evidenced by fewer than 20 reported slope movements out of more than 6,800 fills constructed since 1985.
- The extraction of coal reserves in the study area could be substantially impacted if fills are restricted to small watersheds. The severity of impact to coal recovery correlates with the magnitude of the fill limitations and site-specific and operational factors.

1.4 Actions and Alternatives

In Chapter II, the PEIS identifies a number of proposed actions, presented in three action alternatives in addition to the No Action Alternative, to improve agency decision-making and minimize the adverse effects from MTM/VF. The objective of the coordinated program improvements considered is to integrate application of the CWA and SMCRA to enhance environmental protection associated with MTM/VF operations. The CWA/SMCRA program improvements envisioned include more detailed mine planning and reclamation; clear and common regulatory definitions; development of impact thresholds where feasible; guidance on best management practices; comprehensive baseline data collection; careful predictive impact and alternative analyses, including avoidance and minimization; and appropriate mitigation to offset unavoidable aquatic impacts. The EPA, COE, and OSM propose to promulgate regulations and develop policies or guidance as necessary to establish an integrated surface coal mining regulatory program to minimize environmental impacts from MTM/VF.

The No Action Alternative describes the SMCRA and CWA programs as implemented in 2003. This alternative is the baseline from which to compare all other alternatives.

Alternative 1 provides for the COE, on a case-by-case basis, to make the initial determination of the size, number, and location of valley fills in waters of the U.S. Under this alternative, all MTM/VF projects that would involve proposed valley fills in waters of the U.S. would initially be handled as individual permits (IP) under CWA Section 404. The SMCRA and other permitting agencies would rely, to the extent practicable, on the COE decisions regarding fill placement in waters of the U.S.

Alternative 2 is the preferred alternative because of the improved efficiency, collaboration, division of labor, benefits to the public and applicants, and the recognition that some proposals will likely be suited for IPs, and others best processed as Nationwide Permit (NWP) 21. This alternative is unlike the other two action alternatives in that it integrates the features of SMCRA and CWA programs into a coordinated regulatory process to determine the size, number, and location of valley fills in waters of the U.S. The COE would determine whether an IP under CWA Section 404 is appropriate, relying in part on the SMCRA information provided by the applicant as part of a joint permit application. If so, CWA Section 404(b)(1) and NEPA compliance determinations would be made, similar to that discussed in Alternative 1. If a general permit, such as NWP 21, is appropriate, the COE would process the application following the SMCRA review in a manner similar to the description of the COE review process in Alternative 3. COE NWP 21 decisions would rely, to the greatest extent possible and consistent with legal requirements, on the information and conclusions from the relevant SMCRA review.

Alternative 3 provides for the SMCRA authority to assume the primary role in determining the size, number, and location of valley fills in waters of the U.S. This alternative is based on a procedural presumption by the COE that most MTM/VF applications would be processed as general permits under NWP 21 because the SMCRA review would be the functional equivalent of a CWA Section 404 IP. SMCRA programs would be enhanced through rulemaking to satisfy the informational and review requirements of the CWA Section 404 program, consistent with SMCRA authority. Under this alternative, any off-site mitigation would continue to be assured by the COE under CWA authorization.

The alternative summary table below briefly describes how agency actions would create a coordinated regulatory process for MTM/VF. Following the table are the highlights of the actions proposed to implement the complementary CWA/SMCRA programs.

Table 1. Mountaintop Mining/Valley Fill FPEIS Alternatives Summary

Alternative	Description
No Action	Maintains the regulatory programs, policies, and coordination processes, as well as actions that existed or had been initiated in 2003.
Action Alternative 1	The COE CWA Section 404 program would be the primary regulatory program for determining (on a case-by-case basis) whether and how large valley fills from MTM/VF would be authorized in waters of the U.S. The COE would presume that most projects would require the CWA Section 404 IP process, and general permit NWP 21 authorization would be applicable only in limited circumstances. The COE would perform requisite public interest review as well as appropriate NEPA analysis. As part of the IP process, the COE would largely rely on SMCRA reviews that adequately address terrestrial and community impact issues arising as part of public participation. COE would require mitigation of unavoidable aquatic impacts either through on-site replacement of aquatic functions or by in-kind, off-site watershed improvement projects within the cumulative impact area. The COE would be the lead agency for ESA consultation on aquatic resources and the SMCRA agencies would coordinate with FWS on aquatic and terrestrial species. All other regulatory programs would defer to, or condition decisions on attaining, the requisite CWA Section 404 approval. OSM would consider rulemaking so that the stream buffer zone would be inapplicable to excess spoil disposal in waters of the U.S. OSM would finalize excess spoil provisions to include minimization and alternative analysis more consistent with those under the CWA. Cross-program actions include rulemaking; continued research on MTM/VF impacts, improved data collection, sharing, and analysis; development of Best Management Practices (BMP) and Advance Identification (ADID) evaluations; and agency coordination memorialized by such mechanisms as Memoranda of Agreement. These actions would serve to further minimize the adverse effects on aquatic and terrestrial resources and protect the public.
Action Alternative 2 (Preferred)	The agencies would develop enhanced coordination of regulatory actions, while maintaining independent review and decision-making by each agency. The size, location and number of valley fills allowed in waters of the U.S. would be cooperatively determined by CWA and SMCRA agencies based on a joint

Alternative	Description
	application and under procedures spelled out in such mechanisms as Memoranda of Agreement. OSM would apply functional stream assessments to determine onsite mitigation. OSM rules would be finalized to clarify the stream buffer zone rule and make it more consistent with SMCRA. OSM excess spoil rules would be finalized to provide for fill minimization and alternatives analysis, similar to CWA Section 404(b)(1) Guidelines. The COE would make case-by-case decisions as to NWP or IP processing. Public interest review and NEPA compliance by the COE would occur for IPs and would be informed, to the extent possible, by the SMCRA permit. Mitigation of unavoidable aquatic impacts would be required to the appropriate level. ESA evaluations for IPs would be similar to those in Alternative 1; the SMCRA agency would take the lead for ESA coordination for NWP 21. FWS would retain the ability to consult on unresolved ESA issues for all CWA Section 404 applications. Cross-program actions include rulemaking; improved data collection, sharing and analysis; development of a joint application, harmonized public participation procedures, BMP and ADID evaluations; and close interagency coordination. These actions would serve to further minimize the adverse effects on aquatic and terrestrial resources and protect the public.
Action Alternative 3	The COE would begin processing most MTM/VF projects as NWP 21 and few projects would require IP processing. The SMCRA program would be enhanced as described in Alternative 2 and the SMCRA regulatory authority would assume the primary role of joint application review. The COE, or a state through a programmatic general permit from the COE, would base CWA authorizations largely on the SMCRA review with the addition of adequate off-site mitigation. The COE would require the IP process if its review found an application inadequate due to lack of data, alternatives considered, or mitigation. Satisfaction of ESA would be identical to Alternative 1 and 2. The cross-program actions are identical to Alternative 2 with the exception that no ADIDs would be developed. These actions would serve to further minimize the adverse effects on aquatic and terrestrial resources and protect the public.

The Federal and/or state agencies cooperatively would:

- develop guidance, policies, or institute rulemaking for consistent definitions of stream characteristics, as well as field methods for delineating those characteristics.
- continue to evaluate the effects of mountaintop mining on stream chemistry and biology.
- continue to work with states to further refine the uniform, science-based protocols for assessing ecological function, making permit decisions and establishing mitigation requirements.
- continue to assess aquatic ecosystem restoration and mitigation methods for mined lands and promote demonstration sites.
- incorporate mitigation/compensation monitoring plans into SMCRA/NPDES permit inspection schedules and coordinate SMCRA and CWA requirements to establish financial liability (e.g., bonding sureties) to ensure that reclamation and compensatory mitigation projects are completed successfully.
- work with interested stakeholders to develop a best management practices (BMPs) manual for restoration/replacement of aquatic resources.

- evaluate and coordinate current programs for controlling fugitive dust and blasting fumes from mountaintop MTM/VF operations, and develop BMPs and/or additional regulatory controls to minimize adverse effects, as appropriate.
- develop guidelines for calculating peak discharges for design precipitation events and evaluating flooding risk. In addition, the guidelines would recommend engineering techniques useful in minimizing the risk of flooding.
- implement existing program requirements, as necessary and appropriate, to ensure that MTM/VF is carried out in full compliance with the Endangered Species Act.
- in Alternatives 1 and 2, EPA and the COE would consider designating areas generally unsuitable for fill, referred to as Advanced Identification of Disposal Sites (ADID).
- in Alternatives 2 and 3, the agencies would develop a joint MTM/VF application form.

The COE would:

- continue to refine and calibrate the stream assessment protocol for each COE District where MTM/VF operations are conducted to assess stream conditions and to determine mitigation requirements as part of the permitting process.
- compile data collected through application of the assessment protocol along with PHC, CHIA, antidegradation, NPDES, TMDLs, mitigation projects, and other information into a GIS database.
- use these data to evaluate whether programmatic “bright-line” thresholds, rather than case-by-case minimal individual and cumulative impact determinations, are feasible for CWA Section 404 MTM/VF permits.

The OSM and/or the state SMCRA regulatory authorities would:

- continue rule making to clarify the stream buffer zone rule and require fill minimization and alternatives analysis.
- in conjunction with the PHC, CHIA, and hydrologic reclamation plan, apply the COE stream assessment protocol to consider the required level of onsite mitigation for MTM/VF.
- develop guidelines identifying state-of-the-science BMPs for selecting appropriate growth media, reclamation techniques, revegetation species, and success measurement techniques for accomplishing post-mining land uses involving trees.
- if legislative authority is established by Congress or the states, require reclamation with trees as the post mining land use.

The EPA would:

- develop and propose, as appropriate, criteria for additional chemicals or other parameters (e.g., biological indicators) that would support a modification of existing state water quality standards.

The FWS would:

- continue to work with Federal and state SMCRA and fish and wildlife agencies to implement the 1996 Biological Opinion and streamline the coordination process.
- work with agencies to develop species-specific measures to minimize incidental takes of T&E species.

1.5 Events Since the Publication of the DPEIS

On January 7, 2004, OSM published in the Federal Register proposed changes to regulations regarding excess spoil disposal, the stream buffer zone, and corresponding changes to the stream diversion regulations. On June 16, 2005, OSM determined that the preparation of a separate EIS would be an appropriate mechanism to fully analyze the impacts of the proposed rule and reasonable alternatives that achieve the purposes and need of the proposal. OSM intends that proposed rulemaking would achieve two basic purposes. First, the proposed rule is designed to provide national regulatory guidance to ensure that excess spoil fills are no larger than necessary to accommodate anticipated volume of excess spoil, and to address the adverse environmental effects of excess spoil disposal, particularly impacts on streams. Second, the proposed rule is designed to improve regulatory stability by clarifying the requirements of the stream buffer zone rule in a manner consistent with the underlying authority in SMCRA, and the historic intent of the stream buffer zone as stated in prior versions of the rule. OSM anticipates that a new proposed rule will be published in the Federal Register in conjunction with the release of a draft EIS.

The EPA announced on December 17, 2004 (69 FR75541) the availability of a draft aquatic life criteria document for selenium and requests scientific information, data, and views. The document contains draft water quality criteria recommendations for the protection of freshwater and saltwater aquatic life. EPA is soliciting information, data, and views on issues of science pertaining to the information the Agency used to derive the draft criteria. When completed and published in final form, the revised criteria will replace EPA's current recommended aquatic life criteria for selenium. EPA’s recommended water quality criteria provide technical information for states in adopting water quality standards.

On February 8, 2005, COE, EPA, OSM and FWS signed a Memorandum of Understanding for the purpose of providing concurrent and coordinated review and processing of surface coal mining applications proposing the placement of dredged and/or fill material into waters of the U.S. This is a national umbrella document for surface coal mining designed to improve decision-making using the SMCRA regulatory authority as the suggested focal point for the initial data collection and conducting joint pre-application meetings, public meetings, public notices and site visits. Each agency retains its statutory authorities and independent decision-making responsibilities. A state or Federal SMCRA authority proposing to take this lead role as the focal point for processing will develop specific procedures and sign a local agreement with the appropriate EPA regional offices, FWS field or regional offices and COE districts.

The Federal District Court for the Southern District of West Virginia has enjoined the use of Nationwide Permit 21 in that district court's jurisdiction. *Ohio Valley Environmental Coalition, et al. v. Bulen, et al.*, Nos. 04-2129(L), 04-2137, 04-2402; U.S. Court of Appeals for the Fourth Circuit (*OVEC vs. Bulen*). The COE Huntington District is currently processing surface coal mine applications using the individual permit process. This case is currently under appeal to the 4th Circuit Court of Appeals. A similar lawsuit has been filed in Federal District Court for the Eastern District of Kentucky, see *Kentucky Riverkeeper, Inc. et al. v. Rowlette, et al.*, CV No. 05-181DLB (E.D. Kentucky).

2. Public Review Process

The COE, EPA, FWS, OSM, and WVDEP prepared a DPEIS on mountaintop coal mining and associated valley fills in Appalachia. The agencies sought public comments on the DPEIS in accordance section 102(c) of NEPA which reads in part:

> …Prior to making any detailed statement, the responsible Federal official shall consult with and obtain the comments of any Federal agency which has jurisdiction by law or special expertise with respect to any environmental impact involved. Copies of such statement and the comments and views of the appropriate Federal, State, and local agencies, which are authorized to develop and enforce environmental standards, shall be made available to the President, the Council on Environmental Quality and to the public as provided by section 552 of title 5, United States Code, and shall accompany the proposal through the existing agency review processes.

The Notice of Availability of the DPEIS for public review and comment appeared in the Federal Register dated May 30, 2003 (68 FR32487). The notice announced a 90-day comment period ending August 29, 2003. The period for receipt of comments was extended 130 days to January 6, 2004 and then an additional two weeks to January 21, 2004, based on several requests from stakeholders. Comment period extensions were published in the Federal Register, announced in news releases, and noted on the agencies' web pages. Requesters for comment period extension were notified by e-mail of the extension. The public review period was scheduled to provide concerned agencies and the public an opportunity to review the DPEIS and to offer comments on its adequacy.

The Federal Register notice announced that the DPEIS was available on the Internet at http://www.epa.gov/region3/mtntop/index.htm. The other agencies maintained prominent links to the EPA website. The EPA has distributed copies to known interested parties and organizations, local agency offices, and public libraries as indicated in the document at Chapter VII: Distribution List. An EPA Region 3 toll-free DPEIS request telephone hotline was in operation during the comment period to allow persons to request copies of the DPEIS. Approximately 140 hard copies and 600 CDs of the DPEIS were distributed to agencies and to interested members of the public.

The COE led a communications team for the agencies and distributed a press release on May 29, 2003 to the Associated Press and United Press International. The news release was posted on each agency's web site. A press teleconference was held with twenty national and local media contacts. Follow-up interviews were conducted with other press contacts that could not participate. Wide national coverage of the availability of the DPEIS occurred in print and broadcast media. The news release announced the release of the DPEIS, summarized the DPEIS recommendations, provided brief background information, the libraries where the DPEIS was distributed and contact persons for additional information.

The public was invited to provide written comments during the comment period and oral comments during the two public hearings. Written comments were accepted through the mail or by placing them in a 'comment box' during the public hearings. Comments were also accepted through e-mail at: mountaintop.r3@epa.gov . The first hearing was held on July 22, 2003 at The Forum at The Hal Rogers Center, 101 Bulldog Lane, Hazard, KY 41701. The second hearing was held on July 24, 2003 at the Charleston Civic Center-Little Theater, 200 Civic Center Drive, Charleston, WV 25301. Each hearing had two sessions: the first from 2:00 p.m. to 5:00 p.m. and the second on the same day from 7:00 p.m. to 11:00 p.m. Notices of the public hearings were mailed by the COE to persons who mailed comments to the EPA during the NEPA scoping process.

3. Public Comments Received

During the public review period, 712 letters (including non-form letter e-mails) were received from individuals and organizations. A letter, e-mail or form letter was received from every state in the nation. One letter was received from a group of members of the United States Congress. Three letters were received from Federal agencies. Nine letters were received from state or commonwealth agencies. One hundred seventy six (176) people provided oral comments at the Public Hearings. Eighty three thousand ninety five (83,095) form letters were received. A form letter is defined as identical text sent in an e-mail, letter, or post card. Seventeen different form letters were received. The letters and seventeen different form letters are presented in their entirety on the Internet at http://www.epa.gov/region3/mtntop/index.htm and in the *Public Comment Compendium: Mountaintop Mining/Valley Fills in Appalachia Environmental Impact Statement.*

Table 2. Number of Comments by State

State	State Total	Percent of Total	Letters	E-mails	Oral Statements	Form Letters
AK	182	0.2%	0	0	0	182
AL	385	0.5%	0	5	0	380
AR	297	0.4%	0	0	0	297
AZ	1,437	1.7%	3	2	0	1,432
CA	14,025	16.7%	31	30	0	13,964
CO	2,195	2.6%	4	6	0	2,185
CT	1,007	1.2%	3	4	0	1,000
DC	280	0.3%	11	3	0	266
DE	198	0.2%	0	2	0	196
FL	4,086	4.9%	4	5	0	4,077
GA	1,444	1.7%	6	3	0	1,435
HI	358	0.4%	0	3	0	355
IA	588	0.7%	0	1	0	587
ID	367	0.4%	1	1	0	365
IL	3,237	3.9%	4	8	0	3,225
IN	1,018	1.2%	1	3	0	1,014

State	State Total	Percent of Total	Letters	E-mails	Oral Statements	Form Letters
KS	529	0.6%	0	1	0	528
KY	845	1.0%	84	24	85	652
LA	453	0.5%	0	0	0	453
MA	2,276	2.7%	8	5	0	2,263
MD	1,578	1.9%	5	7	0	1,566
ME	623	0.7%	1	4	0	618
MI	2,406	2.9%	6	7	0	2,393
MN	1,445	1.7%	5	5	0	1,435
MO	1,214	1.4%	0	5	0	1,209
MS	162	0.2%	0	0	0	162
MT	305	0.4%	0	0	0	305
NC	1,687	2.0%	2	7	1	1,677
ND	60	0.1%	0	0	0	60
NE	228	0.3%	0	0	0	228
NH	549	0.7%	0	1	0	548
NJ	2,470	2.9%	0	4	0	2,466
NM	908	1.1%	3	1	0	904
NV	346	0.4%	1	1	0	344
NY	6,414	7.7%	9	17	0	6,388
OH	2,524	3.0%	8	8	1	2,507
OK	364	0.4%	3	0	0	361
OR	2,868	3.4%	2	11	0	2,855
PA	2,977	3.6%	3	10	0	2,964
RI	323	0.4%	0	0	0	323
SC	491	0.6%	0	2	0	489
SD	117	0.1%	0	0	0	117
TN	1,120	1.3%	21	15	4	1,080
TX	3,137	3.7%	3	8	0	3,126
UT	489	0.6%	2	3	0	484
VA	1,934	2.3%	21	15	5	1,893
VT	457	0.5%	2	4	0	451
WA	3,202	3.8%	1	7	0	3,194
WI	1,641	2.0%	0	2	0	1,639
WV	1,401	1.7%	107	36	80	1,178
WY	94	0.1%	0	0	0	94
International	57	0.1%	0	0	0	57
Unidentified	5,185	6.0%	20	41	0	5,124
Total	**83,983**	**100.0%**	**385**	**327**	**176**	**83,095**

4. Organization Of Public Comments For Review And Response

Each letter, e-mail, form letter, and oral statement was reviewed and evaluated. To effectively and efficiently evaluate and respond to the large number of comments, each written and oral comment was grouped into a numbered category. Paragraphs within a letter, e-mail, post card, form letter, or oral statement were identified by a set of numbers that correspond to the numbered category. For example, a paragraph stating a preference for Alternative 3 was given the number 1. These following categories were assigned to paragraphs (or as needed to sentences) within comment letters, e-mails, post cards or oral statements:

Categories

1. Alternatives
2. Role of the General Public
3. Public Involvement
4. Adequacy of DPEIS (NEPA)
5. Water Resources
6. Aquatic Fauna and Flora
7. Terrestrial Fauna and Flora
8. T&E, Candidate, and Species of Concern
9. Cumulative Impacts
10. Social Values
11. Economic Values
12. Government Efficiency
13. Excess Spoil Disposal
14. Stream Habitat and Aquatic Functions
15. Air Quality
16. Blasting (Excluding blasting dust and fumes)
17. Flooding
18. Invasive Species
19. Reclamation

There was some overlap among the comments received concerning the adequacy of the DPEIS. Comments on the adequacy of the range of alternatives in the DPEIS were assigned to category 1. Comments relating to how well the DPEIS fulfills the requirements of NEPA or the stated purpose and need were assigned to category 4. Comments on the adequacy of analysis or how adequately the DPEIS addresses specific topics or resources were assigned to categories 5 through 19 as appropriate. Categories 2 and 3 plus categories 18 and 19 have been combined in the responses to comments.

As part of the comment analysis process, additional numeric designations were made. The categories 5 through 19 were broken into subcategories and comments (paragraphs within a letter) were identified as relating to legal, adequacy of analysis, monitoring or mitigation, specific edit, or factual material. The legal designation was assigned to a comment if a specific regulatory citation or case law was cited. The adequacy of analysis designation was assigned to comments related to mining impacts to the resource category, coverage of the resource in the affected environment section, or the environmental consequences section. Statements of impacts in the context of opposing MTM/VF were assigned a different numeric designation (1-9) under the alternatives category. The monitoring or mitigation designation was assigned to comments regarding monitoring impacts to the resource or mitigating impacts to the resource. The specific edit designation was assigned to comments that specified a section or page of the DPEIS and requested a specific change in a well-developed manner that provided a reason for the requested revision. The factual material designation was assigned to comments that requested additional information such as reports, journal articles, or statistics be considered. See the document, *Public Comment Compendium: Mountaintop Mining/Valley Fills in Appalachia Environmental Impact Statement*, for a list of the numeric designations and their assignment to the comment letters. The reader can request the comment compendium document by contacting EPA's agency representative listed on the signature page. It is also available on the Internet at http://www.epa.gov/region3/mtntop/index.htm.

5. Responses to Comments

5.1 Organization of Responses

Each comment was reviewed, evaluated and summarized. The numeric designations described previously were assigned first; all comments assigned to a given category were evaluated together. The comments were summarized by category. The responses to the comments are organized by category. A short summary of the comments begins the section discussing each category. Comments with responses follow the summary. Comments receiving the same response are grouped together. Changes or additions to the text of the DPEIS made in response to comments are acknowledged in the response and incorporated into the FPEIS through an errata sheet included in Section 6 of this document.

5.2 Responses to Comments by Category

5.2.1 Comments to Which No Response is Required

The agencies received numerous comments to which no response was required. Many comments disagreed with findings or conclusions. Other comments alleged misrepresentation of findings or conclusions. Some comments reflected a difference of opinions or preferred outcomes. In many cases, the commenters provided no additional data to support their claims. The agencies did not identify any commenters' allegations of misstatements of fact other than those specifically addressed in the errata sheet or the responses to comments that identified material inaccuracies or errors.

Some comments reflected a difference of interpretation of the significance of the study conclusions. Further, some of the comments mischaracterized study conclusions as the agencies' conclusions. However, the conclusions in the studies were considered but do not necessarily reflect the conclusions of the agencies. Moreover, the agencies considered numerous options and numerous studies that ultimately were not relied on in developing and analyzing the alternatives in the PEIS. The agencies discussed the bases of their conclusions and analyses throughout the document and in the appendices. In all instances, the agencies carefully considered the best available information in the preparation of this PEIS.

Some commenters suggested that the PEIS justify all or portions of the SMCRA and CWA regulatory program and requested that the PEIS demonstrate the balancing between needs for environmental protection and needs for coal recovery. In addition, many commenters expressed their opinion on the need for the program. Some comments suggested changes to existing programs that were broader than MTM/VF, and consequently are outside the scope of this PEIS. Because these types of comments are not germane to the merits of the PEIS, including the adequacy of the impact analysis, they are not specifically identified and responded to in this document. Those comments were, however, considered.

5.2.2 Category: Alternatives

This category is a grouping of comments related to programmatic action alternatives and the presentation of the No Action Alternative. Comments related to the range of alternatives evaluated, preference for an alternative, description of the existing regulatory program, and the stream buffer zone rule proposal are included in this category. Comments related to CWA Section 404 Individual Permits (IP) and Nationwide Permits (NWP) as well as other aspects of the permitting process are also included in this category. This category corresponds to category 1 in the *Public Comment Compendium* document.

Comments:

> *Mining in general and surface mining in particular is one of the most heavily regulated industrial activities in the nation. Several major environmental statutes have jurisdiction over coal extraction, including a single environmental program*

that was developed by Congress specifically for coal mining. If mining was 'not acceptable from an environmental standpoint, the vast statutes and regulations and the various Federal and state agencies that regulate this activity would not allow a mining permit to be issued. This PEIS confirms the viability of these existing regulatory programs in that no more than temporary, minimal impacts could be linked to surface mining in the region.

Response:

The agencies disagree with the commenter's assertion that "This PEIS confirms the viability of these existing regulatory programs in that no more than temporary, minimal impacts could be linked to surface mining in the region." The PEIS characterized the impacts resulting from MTM/VF activities in Chapter IV.

Comments:

An explanation is requested on how the preferred alternative will minimize the environmental impacts from valley fills.

Response:

The preferred alternative enhances environmental protection and improves efficiency, collaboration, division of labor, benefits to the public and applicants. See Section II.B for a more detailed description of the benefits of the preferred alternative.

Comments:

The DPEIS fails to consider an adequate range of alternatives. Such a narrow range of alternatives is arbitrary and capricious.

The DPEIS violates the National Environmental Policy Act (NEPA) because the DPEIS does not contain a reasonable range of alternatives. The three action alternatives considered in the DPEIS do not represent a legally sufficient range of alternatives because they are merely "process alternatives" without any substantive differences between them, or any substantive difference from the "No Action Alternative." NEPA requires an EIS to present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decision maker and the public, and to rigorously explore and objectively evaluate all reasonable alternatives. The DPEIS further violates NEPA in that it defines the purposes of its action to be so unreasonably narrow that only "process alternatives" can satisfy it, and therefore illegally rejects a broader range of substantive alternatives without analysis of their relative impacts.

No distinction can be made between the No Action Alternative and the three action alternative as they affect cultural, historic, and visual resources in the PEIS study area.

Response:

This is a "programmatic" EIS consistent with the stated DPEIS purpose and need as well as with NEPA, in that it evaluates broad Federal actions such as the adoption of new or revised agency program guidance, policies, and decision-making processes. Each proposed alternative has been developed in a manner to improve environmental protection and better coordinate implementation of CWA, ESA and SMCRA, as compared to the No Action Alternative. As such, the alternatives are reasonable. The DPEIS considered the individual and cumulative environmental impacts of the preferred alternative and the other alternatives in Chapter IV, including cultural, historic, and visual resources. Further, the DPEIS describes certain other alternatives that were considered, which would have made various regulatory changes; and the DPEIS explained why those alternatives were not carried forward in this DPEIS. See Section II.D.

Comments:

The alternative selection ignores strong empirical evidence in the 30 technical studies that indicate the pervasive and permanent impact to the environment, and to public health and culture of communities near MTM/VF operations.

Response:

Studies do indicate that aquatic communities downstream of surface coal mining operations and valley fills are impaired in some cases. Certain chemical parameters (sulfates, specific conductance, selenium) are sometimes elevated downstream of mining or valley fills. Stream reaches below mining and valley fills may have changes in substrate particle size distribution from increased fine material due to sedimentation. Some macroinvertebrate communities change in terms of diversity, population size, and pollution tolerance. However, the sample size and monitoring periods conducted for the PEIS were not considered sufficient to establish firm cause-and-effect relationships between individual pollutants and the decline in particular macroinvertebrate populations. Impairment could not be correlated with the number of fills, their size, age, or construction method. See Section II.C. Action 5 in the PEIS recognizes the value of continued evaluation of the effects of mountaintop mining operations on stream chemistry and biology. Actions 8, 13 and 15 call for additional evaluations on the issues of effectiveness of mitigation restoration, reforestation and on air quality.

Comments:

None of the alternatives in the DPEIS are appropriate and none should be adopted. They are purely process alternatives that should be discarded and replaced with alternatives that actually reduce the cumulative environmental impacts of mountaintop removal mining and valley fills. There is no rational basis for choosing which of the three alternatives is the best. Increased government efficiency at the expense of the human or natural environment is unacceptable.

Response:

The agencies do not agree. All of the alternatives, including the No-Action Alternative are appropriate for a Programmatic EIS. Each of the alternatives provides varying degrees of environmental protection that would reduce the cumulative environmental impacts associated with mountaintop mining. The DPEIS does provide alternatives that if implemented, provide increased protections for the human and natural environments. Alternatives 1, 2 and 3 build upon existing “best science” methods, such as the West Virginia Stream Condition Index and the COE stream functional assessment protocol. In Section II.B.3, there are extensive discussions of how each of the alternatives would provide regulatory and environmental benefits. The basis for choosing the preferred alternative is described in Section II.B.3.b.

Comments:

The use of Advanced Identification (ADID) is unnecessary and duplicative, sufficient resource protection authority exists in SMCRA. CWA and SMCRA require agencies to minimize duplication. Its purpose is to coordinate agency action. ADID is a site-specific action which needs public participation. ADID tends to ignore the possibility that a stream affected by a temporary fill could be restored to a functional status, with only temporary impacts. Under the NWP 21 or IP process, the temporal impacts must be evaluated, and adequate compensation provided. The use of ADID appears to preclude this avenue.

Response:

The agencies do not agree that the use of ADID is unnecessary or duplicative. ADID is an analytical tool under the Clean Water Act that collects data and information in advance of a specific permit application, ADID can be either site-specific or area-wide in focus. See page II.C-36 for a description of ADID. ADID can identify waters of the U.S. that may be generally unsuitable for fills and does not preclude considering whether impacts will be temporary or long-term.

Comments:

The DPEIS violates the Bragg settlement agreement by not developing alternatives that minimize environmental impacts of mountaintop mining. The DPEIS only analyzes process alternatives that are designed to streamline agency decision-making.

Response:

The alternatives analyzed are consistent with the stated purpose of the language in the settlement agreement. The settlement agreement states that the agencies agreed:

> “…to prepare an Environmental Impact Statement (“EIS”) on a proposal to consider developing agency policies, guidance, and coordinated 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 affected by mountaintop mining operations, and to environmental resources that could be affected by the size and location of excess spoil disposal sites in valley fills.”

The DPEIS evaluated four alternatives to agency decision-making processes containing potential policy, guideline, and regulatory changes.

The alternatives are constructed in a manner that requires more environmental information and analysis of the impacts of the operation on environmental resources. All of these proposals were offered as a means to minimize the adverse effects of mountaintop mining operations on the environmental resources. Thus, these alternatives are designed to minimize environmental impacts by coordinating decision-making among the Federal and state agencies responsible for regulating mining activities; developing guidelines on best practices for mining, reclamation, and mitigation; and considering changing policies and regulations. Implementing the preferred alternative is expected to yield an added benefit of increased government efficiency and still fulfill the spirit and intent of the settlement agreement. These are mutually attainable objectives.

Comments:

The DPEIS excludes consideration of any alternatives for more strict limits on MTM/VF.

Response:

The DPEIS considered alternatives that would have established stricter limits on MTM/VF; however, those alternatives were not carried forward, as discussed in detail in Section II.D. Scientific data collected for this PEIS do not clearly identify a basis (i.e., a particular stream segment, fill or watershed size applicable in every situation) for establishing programmatic or absolute restrictions that could prevent "significant degradation."

Comments:

The agencies are required, as a matter of NEPA law, to consider an alternative of "total abandonment of the project"—the no-fill alternative.

Response:

For a programmatic EIS, NEPA does not require agencies to consider an alternative of "total abandonment of the project". Furthermore, the agencies did consider an alternative to prohibit valley fills in waters of the United States, but was not carried forward. See Section II.D.3.

Comments:

All alternatives weaken some states' more restrictive standards, limitations, and requirements of their water quality regulations.

All alternatives are based on analyses not equally applicable or relevant to all of the states affected. Individual state laws and requirements are not adequately addressed in the DPEIS. No studies were done in some states.

Response:

None of the alternatives would weaken state standards. State agencies provided specific information on various state regulatory programs applicable to authorizing MTM/VF activities. The DPEIS only generally describes state and Federal program requirements and does not provide expansive explanation of the many agencies' responsibilities. While West Virginia was the only state that was a signatory to the Bragg settlement agreement, other states in the study area were invited to participate in development of the DPEIS, and they provided information on their programs and otherwise participated as their time and resources permitted. The PEIS focuses on the similarities of the Appalachian coalfield states' programs and affected environments, rather than their unique differences. Any further action supported by this PEIS would involve further coordination with and participation by the appropriate state agencies and would take into account the applicable state laws, regulations, mining methods, and unique environmental conditions.

Comments:

Eliminations of existing protections, such as the Buffer Zone Rule, are not reasonable alternatives. The current DPEIS does not support elimination or revision of the stream buffer zone regulation, and the proposed change is perceived as lessening the current protections afforded to streams.

Response:

The stream buffer zone rule proposal and other regulatory program changes were envisioned and sanctioned by the settlement agreement and do not rely on this NEPA document. OSM is currently proposing changes to the stream buffer zone and excess spoil regulations. The proposal is being accompanied by a separate environmental impact statement analysis and commenters will have the opportunity in that specific rulemaking and NEPA compliance document to further express their concerns. On June 16, 2005, OSM published a NOI for an EIS on the Stream Buffer Zone Rule (70 FR35112).

Comments:

The proposed alternative offers many potential process improvements (e.g. coordinated permitting process, BMPs, ADID, etc.) but inadequate detail on how they would be accomplished.

Response:

As a programmatic DPEIS the document provides general direction for policies, guidance and processes to minimize impacts. Implementation of a preferred alternative may entail additional APA and NEPA procedures that require further input from the affected states and take into account the applicable state laws, regulations, mining methods, and unique environmental conditions.

Comments:

Alternative 1 seems more protective of the environment than other alternatives or no action although it provides insufficient reduction of the environmental impacts of MTM.

Alternative 1 is preferable to the other alternatives – that valley fills will be presumed to require individual 404 permits (IPs) from the Corps of Engineers rather than being authorized by the lesser standards of Nationwide Permit 21 (NWP 21).

Response:

The agencies do not agree that Alternative 1 is more protective of the environment. Alternative 2 is the preferred alternative because it enhances environmental protection and improves efficiency, collaboration, division of labor, benefits to the public and applicants, and the recognition that some proposals will likely be suited for IPs, and others best processed as NWPs. See Section II.B.1.c for a further discussion of Alternative 2.

Comments:

Support for Alternative 3 because permitting responsibility remains with the SMCRA authority and it provides sufficient additional environmental information for regulatory agencies to jointly address the concerns of the stakeholders. There is need to develop new coal mines, whether they are surface or underground.

Based on evidence in the PEIS record, the best alternative would be Alternative 3, including an explanation of why Nationwide Permits under CWA Section 404 are appropriate in most cases for coal mining operations including mountaintop mining and why individual permits are normally not appropriate in most MTM situations.

Response:

Alternative 3 differs from the agencies' preferred Alternative 2, by enhancing the SMCRA programs instead of a coordinated interagency permit process to satisfy the informational and review requirements of the CWA Section 404 program in order to minimize, to the maximum extent possible, the adverse effects of MTM/VF and to create a more effective and efficient permit application review process. Alternative 2 is the preferred alternative because it reduces environmental impacts and improves efficiency, collaboration, division of labor, benefits to the public and applicants, and the recognition that some proposals will likely be suited for IPs, and others best processed as NWPs. See Section II.B.1.c. for a further discussion of Alternative 2.

Comments:

The No Action Alternative is inaccurately characterized. The DPEIS should be stopped in favor of a true "no-action" alternative. This would allow the three regulatory programs to coordinate actions and not set up a single lead program.

The CWA and SMCRA anticipated that coal mining and valley fills would occur and provided for performance standards and regulatory provisions that govern the size, location, and mitigation of fill placement in streams. The DPEIS recommendations for "action alternatives" are not supported by the record of harm included in the technical and scientific studies accompanying this document.

Response:

The "No Action Alternative" must reflect the existing programs and changes underway at the time of the publication of the DPEIS to establish a basis for comparison of alternatives. Consequently, actions that occurred after the settlement agreement, but before publication of the

DPEIS, including the proposed buffer zone rule change, are considered part of the "No Action Alternative". Because regulatory programs are varied as well as dynamic, it would be illogical to compare proposed alternatives to requirements that no longer exist or are proposed to change in the near term. According to CEQ, the "no action" alternative may be thought of in terms of continuing with the present course of action until that action is changed. That is the type of no-action alternative that the DPEIS presented. The "No Action" Alternative was used as a reference (for programs in 2003) from which to compare all other alternatives. The action alternatives have been designed to minimize, to the maximum extent practicable, the environmental impacts from mining.

Comments:

The DPEIS studies clearly establish that greater than minimal adverse environmental effects have occurred, are occurring and will continue to occur as a result of mountaintop removal mining valley fills. Consequently the DPEIS's proposed continued reliance on the use of Nationwide Permits for valley fills is illegal and the general permits cannot provide the basis for considering alternatives under the DPEIS.

COE should require individual permits for any valley fills associated with MTM/VF to ensure that an environmental assessment is performed.

Response:

The agencies do not agree with the commenters' assertions. Each of the alternatives requires the permitting authority to make individual determinations on whether the impacts from a proposed surface coal mining operation will have more than minimal adverse effects in deciding to permit under either a general permit or an individual permit. The agencies have not chosen Alternative 3 as the preferred alternative, in part, because it generally relies on the issuance of permits under NWP 21.

Comments:

The COE is illegally taking action before the FPEIS is completed. The commenter states that the COE has committed to the Alternative 2 prior to the completion of the DPEIS by making public its intent to do a case-by-case analysis of whether it is appropriate to authorize fills under NWP 21 and the COE intends to analyze the fill threshold question completely outside of the NEPA process.

The DPEIS does not address any of the deficiencies noted in the COE's draft Programmatic Environmental Impact Statement for the Nationwide Permit Program (7-31-2001), including inadequate record keeping, lack of mitigation compliance efforts, poor enforcement, and failure of any attempts to quantify and assess the ecological effects of the nationwide permit program.

Response:

Under the existing CWA Section 404 regulatory program the COE is required to make determinations, independent of any other process, on whether an applicant meets the requirements for permitting under the Nationwide Permit Program or must apply for and be approved by an Individual Permit. The COE is not required to suspend its regulatory program pending the outcome of the Nationwide Permit Program EIS or this PEIS. This PEIS is not intended to address any perceived deficiencies that might be noted in the COE's DPEIS for the Nationwide Permit Program.

5.2.3 Category: Role of the General Public and Public Involvement

This category is a grouping of comments related to consideration of public comments, concerns of coalfield citizens, concerns of surface property owners, availability of the DPEIS for review, and location of public meetings. This category corresponds to categories 2 and 3 in the *Public Comment Compendium* document.

Comments:

> *Not enough consideration was given in the DPEIS to the desires of surface property owners. The concerns of citizens in the coalfields area have been largely ignored.*

Response:

In developing the DPEIS and ultimately the FPEIS, the agencies considered all the public comments received during the scoping process and during the public comment period for the DPEIS, including those regarding surface property owners. For example, see the issues identified in Section I.G and Section II.A.3. Actions addressing those concerns that were determined to be significant were described and evaluated in Section II.C. The issues that were considered not to be significant, were outside the scope of the PEIS, or were already addressed by existing programs, were not evaluated in the alternatives. The lead agencies made a number of efforts to engage residents of the communities of the coalfields area in the PEIS process. For examples, as discussed in Section I.G, scoping meetings were held in 1999 in three towns in southern West Virginia (Charleston, Summersville, and Logan). These meetings were for the express purpose of identifying those issues related to mountaintop mining that were of greatest concern to the public. Subsequent to that, meetings were also held for this purpose with citizen and industry groups in West Virginia and Kentucky. Public participation occurred throughout the PEIS process and was integral in determining the scope of the document and in identifying the areas of concern where studies were appropriate.

Comments:

> *No scoping meetings were held in Tennessee, all local libraries did not have copies of the draft document available for public review, and many state and local government agencies were either unaware of the existence of the DPEIS document or unaware that the draft document dealt with more than mountaintop removal mining operations.*

Response:

Although no scoping meetings were held in Tennessee, the agencies believe the effort to involve the public in the development and review of this document met the public participation requirements of NEPA. In their notice in the Federal Register announcing their intent to prepare an EIS, the agencies announced the opportunity for public meetings and invited written comments from the public. EPA also issued a press release announcing the opportunity for public meetings and mailed letters announcing these meetings to approximately 2,500 citizens in the Appalachian coalfield area. In addition, the agencies mailed additional letters requesting comments on the scope of the PEIS, published newspaper notices requesting comments from all of the states in the study area, and posted a notice on the mountaintop mining/valley fill website. The letters and notices described the purpose of the PEIS, provided supplementary information describing the agencies' regulatory responsibilities with respect to mountaintop mining/valley fill activities, and briefly described initial agency concerns to be evaluated in the PEIS. The agencies received and considered over 700 scoping comments.

Copies of the DPEIS on computer disks (CDs) were mailed to approximately 92 libraries throughout the study area. In addition to written notices announcing the availability of the DPEIS, the agencies published a toll-free telephone number from which additional free copies of the DPEIS could be obtained.

Comments:

> *Some indicated that they feared their comments "didn't matter" or may not be read or considered. Others were concerned that because their comments were e-mailed or were form letters instead of individually written comments, their comments would not be "counted" or would somehow be given less consideration than other comments.*

Response:

All comments received during the public comment period were counted, read, and were considered in preparation of the FPEIS. The form in which the comments were submitted (e.g., individual letters, e-mails, and form letters) had no bearing as to the consideration given those comments. Comments and responses will be published for public review and will be maintained as part of the administrative record.

Comments:

> *No public meetings were held after the focus of the preliminary DPEIS changed from alternatives constructed around limits on valley fill sizes to the alternative proposed in the DPEIS released for public review and comment.*

Response:

The preliminary version of the DPEIS was a working document that did not reflect the agencies' official position. The opportunity to comment on the alternatives contained in the preliminary version of the DPEIS but not carried forward was provided during the comment period for the DPEIS.

5.2.4 Category: Adequacy of the PEIS

This category is a grouping of comments related to how well the DPEIS fulfills the requirements of NEPA or the stated purpose and need for the DPEIS. This category corresponds to category 4 in the *Public Comment Compendium* document.

Comments:

The DPEIS's failure to address meaningful alternatives disregards the findings of the studies on mountaintop mining and flies in the face of common sense – and clearly violates the law governing the EIS process. NEPA implementing regulations make clear that an EIS must "present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decisions maker and the public," and to "rigorously explore and objectively evaluate all reasonable alternatives."

Response:

The agencies disagree that the alternatives in the PEIS disregarded the findings of the studies and that the alternatives in the PEIS are not meaningful. This is a "programmatic" EIS consistent with the stated DPEIS purpose and need as well as with NEPA, in that it evaluates broad Federal actions such as the adoption of new or revised agency program guidance, policies, and decision-making processes. Each proposed alternative has been developed in a manner to improve environmental protection and better coordinate implementation of CWA and SMCRA, as compared to the No Action Alternative. As such, the alternatives are reasonable.

A programmatic NEPA document such as this proposes only the direction for future actions. The commenters appear to be looking for a level of detail that has not yet been developed. Information provided as comments on the DPEIS can be considered and utilized to direct further studies by the agencies. There will be further opportunity for peer and/or public involvement as proposed actions are developed.

Comments:

The DPEIS violates the APA. Federal agencies are constrained by the APA (5 USC 701 et seq.) not to adopt any actions that are (i) arbitrary, (ii) capricious, (iii) an abuse of discretion, or (iv) otherwise not in accordance with law, in this case, NEPA. The agency cannot, under law merely disregard environmental factors. That is a violation of NEPA and APA.

Response:

The process of preparing the DPEIS, and the DPEIS itself, violate no applicable requirements of NEPA or the APA. This DPEIS considered all relevant environmental factors that were identified. Accordingly, the agencies conclude that the process is appropriate.

Comments:

The DPEIS violates NEPA because the proposed range of alternatives defers analysis to future Federal actions on a case-by-case basis and as such are not designed to address and reduce the cumulative impacts of permitting decisions.

Response:

The DPEIS considers a variety of potential future actions that are not fully developed. The analysis reflects the programmatic and the not-yet-fully developed character of the alternatives. Any of these alternatives that are actually fully developed and implemented will comply with NEPA as appropriate. The level of analysis in this DPEIS is the level that is feasible and appropriate for a programmatic EIS. The cumulative impact analysis was based on an evaluation of the past 10 years of permitting and extrapolation 10 years into the future based on a constant rate of surface coal mining. See Sections II.C and IV.C for a discussion on cumulative impacts.

Comments:

The DPEIS violates NEPA because it assumes that changing the "stream buffer zone rule" is part of the "No Action" Alternative.

Response:

The "No Action Alternative" must reflect the existing programs and changes underway at the time of the publication of the DPEIS to establish a basis for comparison of alternatives. Consequently, actions that occurred after the settlement agreement, but before publication of the DPEIS (including the proposed buffer zone rule change which is the subject of an independent EIS), are considered part of the "No Action Alternative". Because regulatory programs are varied as well as dynamic, it would be illogical to compare proposed alternatives to requirements that no longer exist or are proposed to change in the near term. According to CEQ, the "no action" alternative may be thought of in terms of continuing with the present course of action until that action is changed. That is the type of No Action Alternative that the DPEIS presented.

Further, the terms of the settlement agreement at paragraph 21 provide that the agencies can continue to modify their respective programs, as appropriate. Paragraph 21 of the settlement agreement states, in its entirety:

> "Except as expressly provided herein, nothing in this Settlement Agreement shall be construed to limit or modify the discretion accorded the Federal agencies by the CWA, SMCRA or general principles of administrative law. Nothing in this Settlement Agreement shall be construed to limit or modify the Federal agencies' discretion to alter, amend, or revised from time to time any actions taken by them pursuant to this Settlement Agreement or to promulgate superseding regulations."

Regulatory program changes were acknowledged in the settlement agreement and any proposed changes would not rely on this NEPA document, and will fulfill NEPA compliance, as appropriate.

Comments:

The DPEIS relies on the effectiveness of in-kind mitigation while admitting that on-site stream reconstruction has never been successfully accomplished.

Response:

The comment suggests that CWA mitigation measures and successes should have been thoroughly evaluated and proven in this DPEIS. This type of thorough evaluation is not feasible in a programmatic EIS. The actions, including CWA mitigation measures, proposed in the DPEIS were presented as possible measures for the agencies to consider developing.

Implementation of these actions would, in many cases, require additional data collection and analysis.

Existing CWA mitigation measures have been and are continuing to require compliance with the standards mandated by the COE prior to approval of the proposed mitigation plan for individual projects. Existing CWA regulations require mitigation for unavoidable impacts to aquatic resources and operators must meet this obligation. That is, if the approved mitigation plan is unsuccessful, the operator must design and implement a plan until success is achieved. See discussion in Section III.D.2.

Comments:

The DPEIS relies solely on a BMP manual to "encourage" reforestation without any analysis of whether it is likely to do so.

Response:

This is a programmatic EIS and it would be premature to attempt to more specifically analyze the effects of a potential BMP manual. See the discussion at page II.C-77.

Comments:

The DPEIS is defective and needs to be re-written; no new mountaintop mining permits should be issued until an EIS is completed and adopted. Due to the massive environmental impacts, NEPA requires such a moratorium. Furthermore, the Clean Water Act dictates that individual permits should be required for such major actions; therefore the current use of nationwide permits is illegal. A moratorium is also warranted because the Federal government has failed to complete an EIS as required, even after 5 years have passed since litigation was initially filed on this issue. Settlement of the litigation was to result in an EIS and better measures to protect the environment. The DPEIS clearly indicates that this is not occurring.

Response:

The alternatives proposed are consistent with the stated purpose of the language in the settlement agreement that initiated this DPEIS. NEPA does not require a moratorium on mining activities until the completion of this PEIS.

Comments:

The DPEIS violates NEPA because it does not address or remedy continuing violations of Federal law. The DPEIS violates the CWA because it assumes continued use of NWPs, even though the DPEIS's own studies demonstrate that the minimal cumulative impact ceiling for NWPS has already been exceeded. Further, the DPEIS violates the CWA because its studies show that MTM/VF activities cause violations of the West Virginia water quality standard for selenium, but the DPEIS does nothing to address those violations. Finally, the DPEIS violates SMCRA, because it admits that MTM/VF activities violate OSM regulations regarding soil practices, but does nothing to address those violations.

The commenter uses studies included in the DPEIS and correspondence between staff as factual support for his arguments.

Response:

The information available to the agencies does not support the commenter's allegation of continuing violations of Federal law. Further, NEPA compliance is not the appropriate process to determine or remedy alleged violations of Federal law. A DPEIS is not an end in itself but a tool to promote environmentally sensitive decision-making. Any relevant violations of federal law would be addressed under the statutory and regulatory provisions of SMCRA and the CWA.

Comments:

The DPEIS violates NEPA because it does not present valid reasons for the elimination of reasonable alternatives from detailed analysis. The DPEIS must present the reasons, in brief discussion, for the elimination of alternatives from detailed study. By failing to articulate valid reasons for the elimination of reasonable alternatives, the DPEIS fails to satisfy this NEPA requirement.

- *Even if there were insufficient information to draw a bright line type of restriction, some type of individual or cumulative restriction on valley filling must be considered.*
- *The DEIS claims that fill restriction alternatives were eliminated from consideration because the MTM/VF operations do not contribute to significant degradation of U.S. waters.*

Response:

The commenter has mischaracterized the agencies' evaluation of fill restriction alternatives. See page II.D-9. The PEIS studies did not conclude that impacts documented below MTM/VF operations caused or contributed to significant degradation of waters of the U.S. 40 CFR 230.10(c). The DPEIS did consider several alternatives to prohibit or restrict valley fills in waters of the United States. The rationales for not carrying forward fill restriction and prohibition alternatives are discussed in Section II.D.

Comments:

Even if sufficient information were not available now to develop fill restrictions, that information must be obtained, because it is essential to choosing among alternatives, and the DPEIS does not demonstrate that the cost of obtaining that information is exorbitant.

Response:

The agencies spent over $5 million to conduct studies investigating various aspects of MTM/VF activities over an approximately 3-year period. These studies were included as appendices to the DPEIS. While these studies were insufficient to determine a bright-line threshold of minimal impacts, they were useful in identifying data gaps and needs for further study. In order to develop an effective trends analysis, the agencies would have to collect and analyze data over an extended period. However, based on extrapolations of funds already expended on these studies and the period over which these studies were conducted, the agencies estimate that approximately $20 million over a minimum 5- to 10-year period would be required to collect data that might be sufficient to carry forward the PEIS alternatives involving categorical fill restrictions on MTM/VF activities as listed in the preliminary DPEIS. Fill restrictions would also require statutory and regulatory program changes. Because these costs are exorbitant, the agencies chose not to continue these expensive studies but rather intend to augment the existing data by those required during the continued implementation of the CWA Section 404 and SMCRA regulatory programs.

Comments:

The DPEIS cannot evade the need to consider fill restrictions on the ground that those restrictions are prohibited by the CWA (using the SBZ to prohibit fills that would be otherwise allowed under the CWA would be a violation of section 702 of SMCRA). This reason for excluding consideration of fill restrictions is erroneous as a matter of law.

Response:

Significant questions remain whether prohibition of fills under the SBZ rule would be consistent with SMCRA Section 702. Regardless of those questions, the OSM began the SBZ rule-making before the DPEIS was published and is preparing a separate nationwide EIS for that rule-making. The proposed SBZ rule-making also pointed out that prohibiting surface mining activities in the SBZ would be inconsistent with SMCRA Section 515(b)(22).

Comments:

The DPEIS mitigation analysis is fundamentally flawed because burial of streams cannot be mitigated. The DPEIS violates NEPA as it fails to analyze effectiveness of proposed mitigation measures. The document wrongly relies on the effectiveness of in-kind mitigation in spite of the fact that the accompanying studies admit that headwater stream reconstruction has never been accomplished and the technology to reconstruct such streams does not exist. Thus there is no rational basis for relying on stream mitigation as a way to reduce impacts of MTM to an environmentally acceptable level. An agency's decision to proceed with a project based on unconsidered, irrational, or inadequately explained assumptions about the efficacy of mitigation measures is "arbitrary and capricious." The DPEIS relies upon mitigation "alternatives" that have little basis in reality, and no credible prospect of success. Accordingly, the DPEIS cannot satisfy NEPA's requirements for a proper alternatives analysis.

Response:

Existing CWA mitigation measures have and continue to require compliance with the standards mandated by the COE prior to approval of the proposed mitigation plan for individual projects. Existing CWA regulations require mitigation for unavoidable impacts to aquatic resources and operators must meet this obligation. That is, if the approved mitigation plan is unsuccessful, the operator must design and implement a plan until success is achieved. See discussion in Section 5.2.4 of this document. Each mitigation proposal submitted to the agencies will be evaluated to determine the likelihood of success. Mitigation for stream impacts is monitored to assure stream functions are achieved. This is a newly developing science.

Comments:

The DPEIS should be withdrawn and a new EIS prepared that meets the requirements of NEPA in its assessment of impacts to migratory birds within the study area, includes additional alternatives to minimize impacts to migratory birds, and provides measures to mitigate unavoidable impacts to migratory birds (Cerulean Warbler).

Response:

A programmatic NEPA document such as this proposes only the direction for future actions. A level of detail to specifically address this concern has not yet been developed. PEIS information provided as comments on the DPEIS can be considered and utilized to direct further studies by the agencies. There will be additional opportunity for peer and/or public involvement as proposed actions are developed.

Comments:

The purpose of the Clean Water Act is to protect and restore the physical, chemical and biological integrity of our nation's waters. Mountaintop mining impairs the physical, chemical and biological integrity of Appalachian streams. The scientific studies done as part of this PEIS have clearly demonstrated that; yet the results of these studies are buried in appendices and their conclusions are inadequately and inaccurately conveyed in the DPEIS. I was particularly concerned by the statement in the Executive Summary that the "opinions and views" of the authors of the technical studies "do not necessarily reflect the position or view of the agencies preparing this EIS". The authors of the technical studies did not have "opinions and views", what they wrote was the result of analyses of scientific data. The quoted statement implies subjectivity in data analysis that is an insult to the authors of those technical studies. These results cannot be simply rejected (or downplayed and ignored as has been done in much of the PEIS) as different "views." The authors have presented logical reasons for their conclusions based on data. In contrast, the agencies have not presented the scientific results or logical arguments that support their "views" (i.e. their choice of the preferred alternative).

Response:

The Executive Summary is not meant to be an exhaustive treatment of each issue. Additional information important to understanding the Executive Summary statements is found in the body of the PEIS. The agencies did not intend to offend the authors of the scientific studies and the change from "opinions and views" to "conclusions" has been indicated on the errata sheet. The agencies disagree that the agencies have not articulated their reasons for choosing the preferred alternative. Rather, the agencies considered all of the scientific and technical studies, together with other available information, and explained their choice of the preferred alternative.

Comments:

The original purpose of the mountaintop removal programmatic EIS was to develop policies and procedures to "minimize, to the maximum extent practicable, the adverse environmental effects to waters of the United States and to fish and

> *wildlife resources from mountaintop removal mining operations, and to environmental resources that could be affected by the size and location of fill material in valley fill sites." The DPEIS has completely abandoned this purpose. It contains no meaningful, substantive alternatives or recommendations that would minimize to any degree the environmental harm caused by mountaintop removal coal mining, let alone policies or procedures to reduce these harms to "the maximum extent practicable."*
>
> *The agencies' chosen "efficiency alternative" does not meet the stated purpose of this EIS, which is to "minimize to the maximum extent practicable, the adverse environmental effects to waters of the US and to fish and wildlife resources affected by MTM operations and to environmental resources that could be affected by the size and location of excess spoil disposal sites in valley fills"*
>
> *In order to fulfill the purpose of the PEIS, and be consistent with the findings of the studies on mountaintop removal, and meet the agencies' obligations under NEPA and other Federal laws, the DPEIS must be rewritten to consider substantive alternatives that would minimize the environmental harm caused by mountaintop removal and select a preferred alternative that would truly protect the resources and people of the region." "None of the alternatives considered in the DPEIS would impose new limits or clear, objective, restrictions on mountaintop removal operations."*

Response:

The alternatives analyzed and actions proposed are consistent with the language in the settlement agreement. The settlement agreement states that the agencies agreed:

> "…to prepare an Environmental Impact Statement ("EIS") on a proposal to consider developing agency policies, guidance, and coordinated 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 affected by mountaintop mining operations, and to environmental resources that could be affected by the size and location of excess spoil disposal sites in valley fills."

While minimizing the adverse impacts of mountaintop mining operations is the goal of the DPEIS, the mechanism to attain that goal is through consideration of different policies, guidance, and coordinated decision-making. The DPEIS evaluated four alternatives to agency decision-making processes and seventeen actions containing potential policy, guideline, and regulatory changes.

The alternatives are constructed in a manner that requires more environmental information and analysis of the impacts of the operation on environmental resources. All of these proposals were offered as a means to minimize the adverse effects of mountaintop mining operations on the environmental resources. Thus, these alternatives analyzed are designed to minimize environmental impacts by coordinating decision-making among the Federal and state agencies responsible for regulating mining activities; developing guidelines on best practices for mining, reclamation, and mitigation; and considering changing policies and regulations. Implementing the preferred alternative may yield an added benefit of increased government efficiency while fulfilling the spirit and intent of the settlement agreement. These are mutually attainable objectives.

Comments:

The DPEIS fails to describe (either in detail or general terms) the environmental resources that would be harmed under the agencies preferred alternative…the omission in the DPEIS itself is especially striking given the scientific studies contained in the appendices so vividly describe the environmental destruction that has been and currently is being caused by mountaintop removal.

Response:

The DPEIS, in Chapter IV describes the environmental consequences of the alternatives, including the preferred alternative. The DPEIS, in Chapter III, Affected Environment and Consequences of MTM/VF, generally characterizes the study area and potential impacts resulting from MTM/VF activities, and describes state and Federal program requirements so as to evaluate coordinated decision-making opportunities to further minimize impacts.

Comments:

The preferred alternative would clearly increase the damage from mountaintop mining by eliminating the Surface Mining Control and Reclamation Act's buffer zone rule that prohibits mining activities that disturb any area within 100 feet of larger streams.

Response:

OSM is currently engaged in an ongoing nationwide SBZ rulemaking that was pending when the DPEIS was published and therefore is discussed in the No Action Alternative. The preferred alternative, like all the other alternatives carried forward for detailed analysis, including the No Action alternative, recognizes that the SBZ rulemaking is also proceeding. The purpose and effects of the SBZ rulemaking are discussed in the proposed rulemaking notice at 69 FR 1035 (Jan 7, 2004) and the Notice of Intent to Prepare an EIS at 70 FR at 35112-35116 (June 16, 2005). The SBZ and excess spoil rulemaking is being accompanied by a separate nationwide EIS. The public should express any concerns they may have regarding that rulemaking in that separate process.

Comments:

The DPEIS presents information, and is based on analysis, not equally applicable or relevant to all states affected by the regulatory programs.

Response:

This PEIS evaluates programmatic alternatives that, if implemented, would be applicable to individual mountaintop mining operations and conditions in Appalachia. The DPEIS provided an opportunity to collect updated data on a range of surface mining impacts and led the agencies to prepare and evaluate the alternatives and actions presented. However, analysis of the alternatives was not dependent on representative data from all locations within the study area. The PEIS focuses on the similarities of the Appalachian coalfield states' programs and affected environments, rather than their unique differences. Any further action supported by this PEIS would involve further coordination with and participation by the appropriate state agencies and would take into account the applicable state laws, regulations, mining methods, and unique environmental conditions.

Before implementing many of the individual actions considered as part of the alternatives, there will be a need for the collection and analysis of additional scientific data and if appropriate, additional public participation and NEPA analysis.

Comments:

The DPEIS fails to address technology changes that will alter projections of future forest loss. DPEIS forest loss projections are probably an underestimate. They also do not consider the anticipated increase in future demand for Appalachian coal due to the planned construction of flue gas desulfurization units (scrubbers) at existing coal-fired generating plants in the study area. For example, the DPEIS projects that TN will issue permits causing the loss of 9,154 acres of forest in 2003 through 2012, but over 5,000 acres of surface mining permits have already been approved between December 2002 and October 2003.

Response:

The level of analysis in this DPEIS is the level that is feasible and appropriate for a programmatic EIS. The cumulative impact analysis was based on an evaluation of the past 10 years of permitting and extrapolation 10 years into the future assuming a constant rate of surface coal mining. See Sections II.C and IV.C for a discussion on cumulative impacts.

5.2.5 Category: Water Resources

This category is a grouping of comments related to water resources, stream chemistry, water regulatory programs, watershed programs, and mining impacts to surface water or groundwater. This category corresponds to category 5 in the *Public Comment Compendium* document.

Comments:

EPA's national water program has worked with states to create comprehensive state watershed approach strategies that actively seek a higher standard of protection for the human environment. However the DPEIS does not address how Federal agencies and the states plan to maintain the comprehensive state watershed approach strategies and continue to approve MTM operations. The DPEIS weakens the state's, COE's, and FWS's standards for programs in sensitive ecosystem watersheds. The proposed changes to MTM/VF permitting would seriously damage all Federal agencies' credibility and accountability to restore and maintain the chemical, physical, and biological integrity of our Nation's waters.

Response:

This PEIS evaluates programmatic alternatives that, if implemented, would be applicable to individual mountaintop mining operations and conditions in steep-slope Appalachia. The DPEIS provided an opportunity to collect updated data on a range of surface mining impacts and led the agencies to prepare and evaluate the alternatives presented. However, analysis of the alternatives was not dependent on representative data from all locations within the study area.

Before implementing many of the individual actions contemplated in this DPEIS, there will be a need for the collection and analysis of additional scientific data and, if appropriate, additional public participation and NEPA analysis. It was not the intention of the agencies that this PEIS provide an exhaustive and definitive compilation or description of each state program requirement.

The DPEIS, in Chapter III, sought to generally characterize the potential impacts and generally describe state and Federal program requirements so as to evaluate coordinated decision-making opportunities to further minimize impacts.

The agencies have no indication that environmental resources or mining impacts in other steep-slope states are vastly different from the data collected in the technical studies commissioned for the DPEIS. More thorough descriptions or voluminous data might more completely define the actions proposed by the DPEIS, but would not likely result in marked differences in the alternatives.

Following the recommended Action 5 in the preferred alternative, the agencies would continue to evaluate the effects of mountaintop mining operations on stream chemistry and biology. As appropriate, EPA would develop and propose criteria for additional chemicals or other parameters (e.g., biological indicators) that would support a modification of existing state water quality standards. [page II.C-44]

And, likewise with recommended Action 6 in the preferred alternative, Federal agencies would continue to work with states to further refine the uniform, science-based protocols for assessing ecological function, making permit decisions, and establishing mitigation requirements. [page II.C-44]

Comments:

Issuing permits to dump mining waste in streams is not legal under the Clean Water Act as passed by Congress. The DPEIS continued reliance on the use of nationwide permits for valley fills is illegal.

Response:

The NEPA process is not the appropriate forum to address allegations of violations of Federal and state law.

Comments:

Specific changes to the description of mining-related impacts to surface water quantity and quality are suggested. The effect of adopting these comments would *be descriptions in the PEIS that definitively concluded that the impacts were adverse.*

The DPEIS contains several serious misstatements of fact, such as it:

- *incorrectly states that "watershed impacts directly attributable to mining and fills could not be distinguished from impacts due to other types of human activity,"*
- *incorrectly claims that 68% of mountaintop mining sites in West Virginia "were to be reclaimed to forestry-related land uses,*
- *incorrectly asserts that "mountaintop mining may not have a significant impact on the biologic integrity of the terrestrial ecosystems," and that ample forest will remain to maintain high biological index scores for wildlife,*
- *incorrectly states that "mined sites may take as long as 120 years or more to attain mature forest conditions," and*
- *incorrectly describes West Virginia's AOC+ protocol as a "fill minimization analysis."*

Response:

These comments are examples of general statements of misrepresentation of, or disagreement with, scientific findings and/or conclusions. The agencies did not identify any commenters' allegations of misstatements of fact other than those specifically addressed in the errata sheet or the responses to comments that identified material inaccuracies or errors. The agencies identified many allegations of inaccuracies that appeared to reflect differences of opinion or preferred outcomes of commenters. Some comments reflected a difference of interpretation of the significance of the study conclusions.

Further, some of the comments characterized as the agencies' misstatements of fact are rather references to studies instead of conclusions made by the agencies. The conclusions in the studies were considered but do not necessarily reflect the position or view of the agencies preparing this PEIS. In many cases, the commenters provided no additional data to support their claims. The agencies discussed the bases of the DPEIS analyses throughout the document and in the appendices. The agencies addressed some of the alleged misstatements of fact in the responses to comments. None of the other alleged misstatements of facts would have led to changes in the description of baseline conditions, analysis of impacts, or revision in the alternatives considered. In all instances, the agencies carefully considered the best available information in the preparation of this PDEIS.

Some commenters suggested that the PEIS justify all or portions of the regulatory program and requested that the PEIS demonstrate the balancing between needs for environmental protection and needs for coal recovery. In addition, many commenters expressed their opinion on the need for the program. Because these types of comments are not on the adequacy of the analysis of the impacts of the preferred alternative and alternatives thereto, they are not specifically identified and responded to in this document. Those comments were, however, considered.

Comments:

The DPEIS fails to consider the long-term impacts to groundwater hydrology from MTM/VF.

Response:

A workshop on mountaintop mining effects on groundwater was held in Charleston, West Virginia on May 9, 2000 during the scoping process for this DPEIS (Appendix G, Part 3 to the DPEIS). As a result of the workshop, groundwater was identified as an issue that did not rise to the level of the most significant issues in the context of mountaintop mining impacts. Information on groundwater was included in Section III.H, Affected Environment. However, in light of the results of the scoping process evaluation of groundwater issues, the agencies focused the PEIS studies on the highest priority issues.

Comments:

Federal and state regulations clearly ban waste disposal, yet in-stream sediment ponds are used for the sole purpose of waste treatment.

Response:

The DPEIS discusses the function of in-stream sediment ponds in describing the current regulatory environment. However, comments advocating change in the use of in-stream sediment ponds are outside the scope of this document.

Comments:

Quality assurance/quality control problems identified with EPA's water chemistry data cause all water chemistry data to be called into question.

Response:

Those data called into question were discarded. The EPA water chemistry study conclusions concerning impacts were supported by QA/QC qualified data.

Comments:

Industry studies showing results different from government studies were excluded because they were not "representative."

Response:

A large array of studies were reviewed and considered, but due to the differences of methodologies used, not all lend themselves to direct comparison. Those discussed are listed in the references.

Comments:

Mining companies should not be allowed to divert water onto private property.

Response:

This PEIS does not grant any permission or rights for mining companies to impact private property owners.

Comments:

Components of documented field case studies may be applicable to selenium mobilization in Appalachia. In contrast to many other contaminants, sources of selenium and significant environmental damage due to selenium have been well documented (Lemly, 1985; Presser, et al., 1994; Lemly, 1997; Hamilton, 1998; Skorupa, 1998; Presser and Piper, 1998; Lemly, 2002; Seiler et al., 2003). Further, an upcoming presentation entitled "Linking Selenium Sources to Ecosystems: Local and Global Perspectives" at the annual meeting of the American Association for the Advancement of Science in February 2004 gives insights into a conceptual model of selenium pollution that is based on the distribution of organic-enriched sedimentary rocks (www.aaas.org/meetings/ Presser and Skorupa, 2003). Our model (detailed in Presser et al., to be released in January 2004) enabled prediction of potential selenium mobilization in areas associated with waste shales, such as valley fills.

Oxidizing, Alkaline Environments — Acid mine drainage is traditionally of concern in mining areas, as it is in the DPEIS study area. However, methods of controlling coal mine drainage (CMD) with alkaline addition may exacerbate the mobility of selenium and hence its loading to the environment. Among the six criteria contributing to selenium contamination was an oxidized, alkaline environment that promotes the formation of selenate, the mobile form of selenium.

Expand Current Selenium Monitoring.

Forecast Selenium Effects Under an Array of Management Scenarios — Determination of a selenium mass balance or budget for the DPEIS watersheds and selenium cycling through the components of the watershed's ecosystems are crucial because of selenium bioaccumulation. A comprehensive linked approach would include all considerations that cause systems to respond differently to selenium contamination. Comparison to multi-media guidelines could be made to assess exposure and risk. Results of a comprehensive monitoring approach then could be used to forecast ecological effects of selenium under an array of scenarios that could result from different resolutions of waste management issues.

Ensure Selenium Methodology with a 0.4 µg/L Detection Limit — The detection limit for the methodology used in the DPEIS stream study was noted as 3 µg /L (Appendix D, Stream Chemistry Final Report, 4/8/02, Table 2), but was further noted that the estimated detection limit for selenium in water using Method 200.8, Inductively Coupled Plasma-Mass Spectrometer, was around 5 µg/L (USEPA Methods Manual, 1983). This methodology and detection limit (3-5 µg/L) may not be sufficient in view of a USEPA criterion of 5 µg/L and ecological effects being of concern at levels of 2 µg/L. Guidance provided by USEPA requires a detection *limit of 0.6 µg/L) (Interim Chemical/Biological Monitoring Protocol for Coal Mining Permit Application, 11/19/00).*

Continue Study of Selenium in Streams — Quality controls issues were resolved concerning analysis of selenium in streams. However, results from Lab 1 were discarded mainly because of elevated levels in Blanks. Duplicating this study with improved methodology and detection limit for selenium may prove informative.

The technical studies demonstrate that water quality standards for selenium were being violated in West Virginia below valley fills and that the DPEIS is not proposing any remedies for those violations. The DPEIS must propose remedies to eliminate all existing and potential stream degradation due to contamination from MTM/VF activities.

Excess spoil having elevated selenium levels is placed in valley fills thus causing adverse impacts to water chemistry.

Response:

The CWA Section 303(d) list of 2004 prepared by WVDEP and approved by EPA recognized some selenium impaired streams. EPA finalized in March 2004 a TMDL addressing selenium for the Guyandotte River Watershed, including the Mud River. WVDEP expects to finalize a TMDL on the Coal River in 2005 that addresses selenium. TMDLs could be developed for other streams.

The EPA formally published proposed revisions to the Aquatic Life Water Quality Criteria for selenium in December, 2004. The revision process was initiated prior to the DPEIS process and will continue after the PEIS is finalized. Recent selenium workshops (April and August, 2004), sponsored by USGS have focused interest on on-going and potential studies that will further the assessment of the occurrence and impact of selenium in the Appalachian region.

Activities authorized under SMCRA and CWA Section 404 proposals for surface coal mining operations must comply with any applicable NPDES effluent limits. The effluent limits for point sources associated with coal mining consider industry-wide treatment technology and address specific concentration for iron, manganese, pH and suspended solids as well as measures to protect aquatic life and human health. Under the CWA no activity is allowed to violate Water Quality Criteria (including selenium) in the waters of the United States. The Discharge Monitoring Reports (DMRs) required in NPDES permits provide for industry and the state regulatory agencies monitoring data to indicate compliance and tools to protect stream quality. This feature of the CWA program helps guard against impairment levels affecting designated uses.

The studies sponsored by the PEIS were intended to provide the agencies information on trends identifying where a potential problem may exist; they were not developed to the extent needed to give definite answers to specific program changes or revisions especially on a regional or national level. The results of the studies developed for the PEIS are the reason there are actions in the PEIS to identify the need for additional studies. Additional studies on selenium in particular are part of actions taking place parallel to the PEIS, but will result in separate NEPA documents.

Comments:

Concerns about elevated selenium at test sites are minimized when considered in light of the latest scientific data on aquatic toxicity of selenium. EPA's current nationally recommended chronic criterion for selenium (5 µg/l in the water column) and 20 µg/l acute criterion have been adopted by many States and utilized in water quality standards programs. However, based upon the latest scientific knowledge on selenium toxicity, EPA made a decision to update the acute and chronic criteria for selenium and published, in March 2002, a draft selenium criteria document.

EPA's draft document proposes a revised freshwater acute criterion (185 µg/l) in the water column and 7.9 µg/g (dry weight) in fish tissue that is considerably higher than the current national criterion. It is important to note that in some geographic areas in the study area background levels of total selenium exceed 20 ppb, yet no acute toxic effects are observed. Therefore, the levels of concern expressed in the PEIS studies become much less significant when considered pursuant to the agency's proposed revised criteria. See Draft Aquatic Life Water Quality Criteria for Selenium 2002, *EPA Contract No. 68-C6-0036 (March 2002 Draft).*

EPA is currently in the process of revising the suggested water quality standard for selenium. In February 2002 the agency published a draft of these revisions. Among the conclusions and observations included in the draft document are several that are relevant to this DPEIS and the assertion that detectable selenium concentrations in the water column are indicative of negative impacts.

A commenter supports, as contemplated in Action 5, a meaningful review or reanalysis of current water quality standards and use designations, particularly in light of new scientific evidence suggesting the current national water quality criteria for selenium may be over-protective.

Response:

The EPA formally published proposed revisions to the selenium criteria in December, 2004, and requested public comments. EPA has not yet processed those comments or arrived at a final decision on the proposed revisions. If and when EPA decides that criteria changes are warranted, the agency will publish that information in the Federal Register. Until then, the criteria in effect at the time the DPEIS was published remain in effect.

Comments:

The reference to unpublished USFWS information on selenium data from a lake in the study area is inappropriate and should be deleted from the PEIS.

It is incorrect to extend the results of the Lemly studies to this PEIS because the Lemly studies were conducted in a lotic rather than lentic environment.

Response:

The FWS information has been added to the errata. According to a January 16, 2004 letter from David Densmore, FWS to Allyn Turner, West Virginia Department of Environmental Protection: “In 2003 the FWS collected fish in streams downstream of valley fills, where earlier water quality analysis [Appendix D] had revealed high selenium concentrations. The results demonstrated that the selenium is biologically available for uptake into the food chain, and that violations of the EPA selenium water quality criteria may result in selenium concentrations in fish that could adversely affect fish reproduction. In some cases, fish tissue concentrations were near levels believed to pose a risk to fish-eating birds. It is likely that benthic invertebrates in some of these streams would be similarly contaminated, thereby posing a risk to birds such as Louisiana waterthrush that depend upon aquatic insects as a food supply.” (January 16, 2004, letter from David Densmore, FWS, to Allyn Turner, West Virginia Department of Environmental Protection). These data demonstrate that selenium can bioaccumulate in lotic (flowing) as well as lentic (non-flowing) environments. No change to the DPEIS is warranted.

Comments:

Further evaluation of stream chemistry and further investigation into the linkage between stream chemistry and stream biotic community and structure are needed.

Response:

Actions to further evaluate the linkage between stream chemistry and the biotic community are included in the DPEIS. These actions could deal directly with stream impairment by: 1) developing additional water quality standards based on additional study and data collection regarding impacts; and, 2) using monitoring protocols for aquatic ecosystem functional assessment. Other actions developed for issues such as Section III.C.3 Direct Stream Loss; Section III.C.5 Fill Minimization; Section III.C.6. Stream Habitat and Aquatic Functions; Section III.C.7. Cumulative Impacts; and Section III.C.8. Deforestation could mitigate stream impairment as well. [page II.C-44]

Comments:

Industry is not opposed to providing innovative mitigation or paying for damages that have occurred, however, the government agencies are not interested in industry’s proposals to provide sewer lines to clean up streams. Mitigation also should include removing trash from streams.

Response:

Stream habitat and functions lost through mining and filling are subject to amelioration through mitigation. Although providing sewer projects or removing trash from streams may increase water quality in adjacent areas it does not provide in-kind replacement of habitat and functions of headwater streams. Separate CWA programs assess responsibility and provide opportunities to improve water quality concerning inadequate sewage treatment systems. The COE is considering the use of general watershed improvements as an opportunity for mitigation.

Comments:

The statement on page ES-4 that mining is "characterized by an increase in minerals in the water" is a misrepresentation of the data presented. Sulfate concentrations are 41 times greater on mined sites; total dissolve solids are 16 times greater; calcium, magnesium, total hardness is 21 times greater; conductivity is 5 times greater; selenium is over 7 times greater; selenium median value is twice the EPA safe drinking water standard, and 66 violations of drinking water standards for selenium were found below valley fill sites. These are very significant impacts on the chemical integrity of our Nation's waters that have not been addressed in the DPEIS. These kinds of changes impair biological integrity of the waters as well as pose threats to human health.

Response:

The agencies do not agree that the statement on page ES-4 is a misrepresentation; it is a general statement in the Executive Summary. A full discussion on this issue is in Section IV.B.1.b. (page IV.B-4).

Comments:

The evidence does not show a clear impact on the study streams by MTM/VF activities but indicates changes typical of any large-scale development project, e.g. road construction or residential development.

Finding selenium concentrations above the suggested criteria can be expected given the overall background levels of selenium present in the native soils of the area. Similar concentrations can be expected below any land disturbing activity in the region.

Response:

The available studies do not conclusively distinguish impacts downstream of MTM/VF from impacts of other activities within the watershed. The commenters provided no data to support these claims.

Comments:

The DPEIS is critically deficient because 1) supporting documentation failed to adequately quantify and analyze the effects of selenium on aquatic life; and 2) proposed alternatives failed to address the protection of aquatic life from potential adverse effects of selenium. The DPEIS has left out 1) fundamental data on selenium concentrations in sediment, invertebrates, fish tissue, and bird eggs; and 2) information on dietary pathways and vulnerable predator species. Proposed control measures to neutralize discharges with alkaline addition may exacerbate the mobility of selenium and hence it's loading to the environment.

Response:

The studies conducted as part of the DPEIS do show an impact from MTM/VF activities to water chemistry downstream of surface coal mining operations and valley fills and indicate that in some cases aquatic communities are impaired. However, the sample size and monitoring periods conducted for the PEIS were not considered sufficient to establish firm cause-and-effect relationships between individual pollutants and the decline in particular macroinvertebrate populations. Impairment could not be correlated with the number of fills, their size, age, or construction method [page II.C-38].

The USEPA formally published proposed revisions to the Aquatic Life Water Quality Criteria for selenium in December 2004. The revision process was initiated prior to the PEIS process and has not yet concluded. Recent selenium workshops (April and August, 2004), sponsored by USGS have focused interest on on-going and potential studies that will further the assessment of the occurrence and impact of selenium in the Appalachian region. Until a revised standard is adopted the states are required to abide by the currently adopted standards.

Since selenium is bioaccumlated, it is not expected to be directly toxic to fish collected in the fisheries studies. However, selenium is one of the most toxic micronutrient to mammals of all biologically essential elements; fish and birds are very sensitive to selenium contamination in an aquatic environment. Selenium is passed from parents to offspring in eggs and, during critical stages of development and growth, is substituted for sulfur in amino acids that form structural and functional proteins. As selenium exposure increases, toxic effects can range from suppression of the immune system, to reduced juvenile growth, to embryo mortality, to mass wasting in adults, to teratogenesis (lethal or sub-lethal deformities) in juveniles, to juvenile mortality, and finally to adult mortality. See Draft Aquatic Life Water Quality Criteria for Selenium 2002 and 69 FR75541.

Comments:

Two reports on the Ballard Fork gages (Messinger, 2003; Messinger and Paybins, 2003), which were produced by USGS West Virginia District as part of the PEIS process, should be discussed in section III.D. Both reports contain noteworthy information on total flows, stormflow characteristics, and seasonal evapotranspiration losses.

Response:

The information contained in the draft reports was considered in the development of Section III.D. of the DPEIS; however, they did not provide significant new information relevant to Section III.D. beyond information already available from other studies. Therefore, these studies were not cited in Section III.D. One of these draft reports was cited in Section III.H. and both of these reports were included in Appendix H, Part 1.

Comments:

On page III.D-18 — The commenter recommends that the discussions of stream creation include additional information on watershed hydrology, such as the Variable Source Area Concept (Hewlett and Hibbert, 1967), that is, that water seeps downhill through soil until it reaches a confining layer, that streams form in saturated soil areas on the land surface, and that the area of saturated soil that contributes to streamflow is variable through time. In light of the principles of watershed hydrology, stream creation is very difficult and may not be practical, at least if only natural channel design is to be applied to ditch construction.

Response:

The difficulty of intercepting the groundwater and surface water hydrology for stream construction is recognized by the agencies evaluating mitigation projects. Watershed hydrology is one of many factors the agencies take into consideration when evaluating compensatory mitigation for stream impacts. Each mitigation proposal submitted to the agencies will be evaluated to determine the likelihood of success. Mitigation for stream impacts is monitored to assure stream functions are achieved. This is a newly developing science.

5.2.6 Category: Aquatic Fauna and Flora

This category is a grouping of comments on mining impacts to aquatic invertebrates and benthic invertebrate studies. This category also includes comments on fish population studies. This category corresponds to category 6 in the *Public Comment Compendium* document.

Comments:

The DPEIS fails to recognize that salamanders and mussels, for example, have particular difficulty adapting or changing habitat to new streams.

The DPEIS fails to fully consider the value of these forests and the terrestrial and aquatic species dependent on them and the very real predictability of their destruction - and extinction by widespread mountaintop mining and valley fills.

Response:

In Section IV.D (pages IV.D-2 and 4), the agencies recognized that there would likely be a shift to drier habitats that may negatively affect species dependent on wetter habitats, such as salamanders.

Comments:

A consistent definition is needed to establish where headwater streams start. Topographic maps greatly underestimate their abundance and length. The commenter suggests that a much better point would be where aquatic species with year-long or multi-year life cycles are found (see Appendix D, Stout, et al. study).

Response:

There are currently different definitions of jurisdictional waters for CWA, SMCRA and state law as administered by various state and Federal agencies. There is an action in the preferred alternative in the DPEIS which proposes that the Federal and/or state agencies will develop guidance, policies or institute rule-making for consistent definitions of stream characteristics as well as field methods for delineating those characteristics. [Section II.C.2.b]

Comments:

Better stream protection from direct and indirect effects will not result from improved characterization of aquatic resources if the proposed assessment is limited to family or generic level identification of organisms.

Response:

Aquatic resource characterization methods are still being evaluated by the agencies. The commenter's concerns will be taken into consideration.

Comments:

Statements regarding fish impairment in the DPEIS are incorrect. The general reasoning in support of this belief is contained in the following paragraph:

> *"Mountaintop mining will potentially impact only 4.10% of the total stream miles in the study area, 60% of which are first order headwater streams, dispelling any myth that mining and valley fills are eradicating all headwater streams. Benthic research has demonstrated that abundance remains high below fills and that the ponds and wetlands created during reclamation are providing their own energy inputs to the stream reaches. The USGS fisheries survey confirms the benthic research, finding that heavily surface mined watersheds supported healthy and diverse fish populations."*

Response:

While some studies have found that benthic invertebrate abundance downstream of valley fills is not statistically decreased compared to upstream, abundance is not necessarily a good measure of ecosystem health. For example, some benthic organisms are more sensitive to certain pollutants than other organisms; when the pollution eliminates the sensitive organisms, the more tolerant organisms have less competition for food and space, and are able to increase in numbers — resulting in no change in abundance, although the biological integrity of the benthic community has been decreased. Benthic invertebrate studies conducted by a number of government and industry researchers, and summarized in the DPEIS [Appendix D, Fulk 2003], concluded that biological integrity is reduced downstream of MTM/VF. Concerning energy inputs due to ponds and wetlands, no data specific to organic matter or energy were gathered to address this question during the DPEIS process. Finally, the commenter has misinterpreted the USGS study (Messinger, T., and D. B. Chambers. 2001. Fish communities and their relation to environmental factors in the Kanawha River basin, West Virginia, Virginia, and North Carolina, 1997-98." USGS Charleston, West Virginia). That document clearly states (page 39) that "Because of the effects of zoogeography and the lack of unmined, medium-sized streams in the coal-mining region, conclusions could not be made about the effects of coal mining on fish communities."

Comments:

The statement in the DPEIS on selenium concentrations in excess of AWQC at most of the filled sites is misplaced given the level of understanding relative to selenium impacts and technical research that found healthy aquatic communities in watersheds exceeding the suggested water quality criteria for selenium.

Response:

The DPEIS noted [Appendix D] that the West Virginia Stream Condition Index for invertebrates was negatively correlated with selenium concentrations. In other words, as selenium concentrations increase, benthic invertebrate population health declines. In addition, the scientific literature demonstrates that selenium is most problematic from a food chain standpoint, causing reproductive failure in fish and birds that consume contaminated organisms.

Comments:

The balance of DPEIS technical research has identified a shift in benthic communities, a shift that can be attributed to a number of factors and a shift that is by no means disadvantageous. Similar shifts were found below mining related disturbance that did not involve valley fill activities at a site outside of the PEIS study region suggesting that similar results can be expected below any disturbance within the general Appalachian region.

The commenter has presented the results of studies conducted for the PEIS, by coal operators in conjunction with the DPEIS, independent of the DPEIS but within the study area and outside of the study area but related to the streams in the study area. The bulk of this research documents a shift in the biologic community below disturbance. There is some question as to how directly this shift can be correlated to particular water column parameters including conductivity.

In Appendix D, A Survey of the Conditions of Streams in the Primary Region of Mountaintop Mining Valley Fill Coal Mining, streams assessed during the study that contained residential development were the most impaired. Because several stressors, including mining activities and residential development could cause the observed impairments, no specific conclusions were reached. Although issues regarding conditions in sediment control ditches associated with fill construction are identified, very little useful data was provided to characterize conditions in those structures.

From the results of the EPA streams study and other related research, it is apparent that the aquatic communities were different among the classes of invertebrate species, but not impaired. The elimination of the mayfly taxa cannot be linked to impairment as the DPEIS narrative attempts to do.

Response:

The commenters are referred to Appendix D of the DPEIS (e.g., Fulk et al., 2003) for information on the reduction in species diversity and increase in pollution-tolerant macroinvertebrate and fish species downstream of valley fills. Comments that similar results would be expected downstream of any disturbance in Appalachia are not substantiated; furthermore, this DPEIS evaluated impacts related to mountaintop mining and valley fills, not all land disturbance in the region. Finally, the absence of mayflies from streams where they are expected to occur is widely recognized throughout the scientific community as indicative of water quality impairment. No change to the DPEIS is warranted.

Comments:

On page IV.D-5, Fish Populations — This section is brief and not very informative regarding mining impacts on fish populations. Additional information *(topic material or concepts) should be provided in the section. Coverage of the topic should be similar to that provided in section b.*

Response:

Additional information on fish populations is provided in Appendix D (Stauffer and Ferreri, 2002).

Comments:

Kentucky Mountaintop Mining Benthic Macroinvertebrate Survey — the study has very limited usefulness because it was specific to only four Kentucky counties and samples were collected just a single time at twelve stream sites in May of 2000. The study's conclusions that MTM/VF construction negatively impacts benthic health do not match similar study results from Virginia. See research report "Ecotoxicological Evaluation of Hollow Fill Drainages in Low Order Streams in the Appalachian Mountains of Virginia and West Virginia" by Timothy Merricks with Dr. Donald Cherry. Also, the last paragraph of the study report indicates that the impacts to benthic health from MTM/VF activities relate to deforestation. Forest is the most common post-mining land use in Virginia. This differs from Kentucky reclamation practices and therefore the conclusions of this report do not seem applicable to Virginia.

No Virginia study information is included in Appendix D, The Value of Headwater Streams: Results of a Workshop, State College, PA, April 13, 1999. It should be noted in the PEIS that remining of AML areas would often reconnect headwater streams to lower reaches. These streams were originally disrupted by AML mining activities. The headwaters empty onto the AML bench, then flow down the bench, eventually flowing over the bench at a low point by passing the lower reach of the stream. By remining and backfilling the AML highwalls, these streams can be re-connected.

Ecological Assessment of Streams in the Coal Mining Region of West Virginia Using Data Collected by the EPA and Environmental Consulting Firms — As with the Kentucky report, the study has limited usefulness because it was specific to West Virginia. Seasonal data was collected from five West Virginia watersheds. No Virginia study information was included. The study's conclusions that mountain top mining and valley fill construction negatively impacts benthic health do not necessarily match similar study results from Virginia and West Virginia.

Response:

The studies provided adequate information to evaluate the alternatives, but did not provide specific data for each state or mine. Because this is a programmatic EIS, it was not necessary to collect representative data from each state and the analysis of the alternatives was not dependent on representative data from all locations within the study area. Any further action could involve more data collection and analysis as well as further coordination with the appropriate state agencies, and will take into account, as appropriate, the applicable state requirements, mining methods, and unique environmental conditions.

Comments:

On page III.D-20 (third paragraph), for nutrient cycling, it is well known that aquatic insects play a role in all aquatic ecosystems because all living organisms cycle nutrients. A more reasonable question that should be addressed in this section is whether nutrient cycling in such nutrient-poor systems are important to areas larger than the created wetlands.

Response:

The DPEIS considered nutrient cycling in a larger watershed context and discussed it in detail in Section III.C.1.b.4. (page III.C-5)

Comments:

Part of the preferred alternative calls for the COE to do a functional assessment of the stream before it is buried by the valley fill. Then the COE is to make sure that there is no net loss after mitigation. The COE functional assessment does not appropriately integrate rare invertebrates into the functional assessment because it takes highly trained biologists to identify rare invertebrates. If the right things are not identified before the valley fills, how can the mitigation adequately compensate for the loss?

Response:

Regulatory requirements are currently in place to collect information necessary for the COE's permitting decisions. The COE functional assessment protocol uses typical stream survey methods that are rapid assessment techniques. Although these techniques are used to characterize the quality of the streams prior to making the permit decision, they may not identify certain new or rare invertebrate species. The identification of new or rare species may require genetic testing or other extensive analysis. Under the preferred alternative, the COE would continue to refine and calibrate the stream assessment protocol within each ecoregion.

Comments:

On page III.D-21, subsection e.1. Onsite, top of the page, lines 7-9, the statement "However, it is not known whether the organic matter processing that occurs in created wetlands would mimic the processing found in a natural stream system." does not consider much information that is known about the nature of wetlands compared to the nature of streams. Wetlands, by their nature, trap and conserve organic matter, and function as organic matter sinks; whatever organic material wetlands retain, the material tends to be dissolved, rather than undissolved. Streams, by virtue of flowing, tend to transport organic matter (and whatever else they contain) downstream. It is unlikely that organic matter processing in created wetlands would provide processing similar to that provided by small streams. The commenter recommends that the statement be modified to emphasize these differing roles of streams and wetlands.

Response:

The DPEIS statement was meant to reflect the lack of data comparing organic matter downstream of created wetlands with organic matter in a natural stream. However, the commenter's point is accurate, and this sentence is noted as deleted on the errata.

Comments:

Since trees do not grow well on reclaimed land and ponds do not replace streams, the replacement of headwater streams on reclaimed land will not offset the loss due to valley fills.

Response:

With natural stream design and a riparian buffer of trees planted on the reclaimed mine site, functions of ephemeral and/or intermittent streams may be replaced. Monitoring the effectiveness of such mitigation plans will continue and, if they are not effective, will require additional offsite mitigation such as stabilizing stream banks, reducing erosion and planting riparian vegetation to reduce the impacts of valley fills on the watershed.

5.2.7 Category: Terrestrial Fauna and Flora

This category is a grouping of comments related to forest habitats, post mining forest regeneration or natural succession, terrestrial habitats, terrestrial animals including migratory birds and terrestrial studies. This category corresponds to category 7 in the *Public Comment Compendium document.*

Comments:

There is no evidence that significant forest regeneration is occurring on valley fills. Hardwood forest recovers within several decades following logging, or even succession from agriculture, insects and disease; there is no evidence of such a succession on valley fills.

Response:

DPEIS studies have indicated that historically, reestablishing hardwood forests on reclaimed mine sites has had limited success. However, studies by Virginia Polytechnic Institute and State University and University of Kentucky, described in Section IV.C, identified hardwood reforestation measures that, if implemented, may be successful. Action 13, which is part of the preferred alternative, was proposed to help develop methods for and promote the use of reforestation on surface mined lands.

Comments:

An explanation is requested on the following sentences on page III.F-9, which appear to contradict each other since salamanders are amphibians:

> *"Amphibian and reptile species richness and abundance do not differ between grassland, shrub/pole, fragmented forest, and intact forest habitats from mountaintop mine sites in southern West Virginia" (Wood and Edwards, 2001) [see Appendix E for details].*

"Salamanders appear to be less common in the grasslands of reclaimed mountaintop mining sites than in the nearby forests" (Wood and Edwards, 2001).

Response:

The first sentence refers to amphibians and reptiles collectively; the second, to only salamanders. The relative proportion of amphibians and reptiles changes from one habitat type to another, particularly from wetter habitat types to drier ones. A clarification to more accurately reflect the language of the study was made to Section III.F.3.c on the errata sheet.

Comments:

Bill Mackey, former head of forestry in West Virginia, should have been interviewed and his concerns addressed in the document. In addition, other comments asserted that no regional experts were used for these studies, only outside experts.

Response:

Four of the five terrestrial studies were conducted by regional experts, including West Virginia University and Concord College (Athens, West Virginia). See Table II.A.-1 in Section II.A.2 for a list of all of the technical studies and their authors. In addition, the preferred alternative includes an action to develop a Best Management Practice Manual for reforestation with input from the local research community.

Comments:

Information from the Society of American Foresters published data indicating that tree planting and the forest industry are thriving in the United States. These data contradict studies in the DPEIS that deal with forestry and these conflicts should be reconciled.

Response:

Information from the Society of American Foresters provided by the commenter concerns forestry production on a national scale. The DPEIS evaluated impacts to forest only within the study area. A DPEIS study (Handel, 2003) focused on mountaintop mining sites in West Virginia, and found that reforestation is not occurring through natural succession on most of the MTM/VF areas examined.

Comments:

The DPEIS fails to identify and analyze effective mitigation measures to reduce bird losses. The DPEIS suggestion that reforestation is a panacea to mitigate the negative effects of mining on interior forest habitat within the foreseeable future is wrong and misleading. BMPs (Action 13) would be voluntary, and state or Federal legislative change (Action 14) could take years. Also, it is inappropriate to consider replacing high quality forest habitat with grassland habitat for "rare" eastern grassland species that didn't occur here historically.

The commenter supports Action 13 to develop a BMP manual for growth media and reclamation with trees. The DPEIS recognizes that; 'impacts to soils from MTM/VF are not irreversible and that over time, soils similar to those that existed prior to mining are likely to be re-established on reclaimed mine sites'. EIS IV C-7. This is an area where OSM rulemaking could make a significant contribution to minimizing the impact of MTM operations by removing existing impediments to planting trees.

Maintaining extensive tracts of mature deciduous forests to support the high diversity of mature forest birds, many of which are high conservation concern species, is one of the highest Partners in Flight conservation priorities within the PEIS study area. The commenter encourages every effort to minimize the removal and fragmentation of existing mature forest habitat in the PEIS study area.

The DPEIS fails to identify and analyze reasonable alternatives to avoid bird losses, a fatal flaw. Combined with the fatal flaw of not properly addressing priority bird species, the DPEIS fails to comply with NEPA.

The only mitigation offered in the DPEIS for the destruction of large areas of hardwood forest habitat by mining operations is a suggestion that the mine sites could be reforested after operations cease. Convincing evidence that a hardwood forest, essentially the same as the one removed during mining, can be reestablished in a reasonable amount of time, needs to be presented before this method can be offered as mitigation for the loss of hundreds of thousands of acres of biologically diverse hardwood forest habitat.

Response:

The DPEIS acknowledges the importance of study area forest habitats in the DPEIS study area to migratory birds and other wildlife, and proposed Action 13, included in the preferred alternative, would develop and promote guidelines for reforestation of surface mined areas. Removal of the trees before surface coal mining operations is required under SMCRA, although mining is not the only reason that logging occurs in this region. Reforestation provides the opportunity for the long-term restoration of habitat. Although establishing grass may be an element in the reclamation process required under SMCRA, Action 13 is anticipated to encourage reforestation with species that would approximate native forest habitat. In the meantime, agencies will continue to consider the cumulative impacts on terrestrial habitats when evaluating projects on a permit-by-permit basis. Impacts of the alternatives on bird species were considered in the DPEIS. The preferred alternative includes Action 13 to foster reforestation to ameliorate the impacts of lost forest habitat.

The agencies agree that BMP's are voluntary and that legislative change might take years. However, for the reasons outlined in the description of the alternatives, the agencies do not regard these factors as barriers to success.

Comments:

The failure to include alternatives that would protect some migratory bird habitat violates Executive Order 13186, which requires Federal agencies to cooperate with FWS to promote the conservation of migratory birds.

Response:

In January 2001, the President signed Executive Order 13186 directing Federal agencies to conserve migratory birds. The Executive Order directs each Federal agency taking actions having or likely to have a negative impact on migratory bird populations to work with the FWS to develop an agreement to conserve those birds. The protocols developed by the consultation are intended to guide future agency regulatory actions and policy decisions; renewal of permits, contracts or other agreements; and the creation of or revisions to land management plans.

In addition to avoiding or minimizing impacts to migratory bird populations, agencies are expected to take reasonable steps that include restoring and enhancing habitat, preventing or abating pollution affecting birds, and incorporating migratory bird conservation into agency planning processes whenever possible. Because the Executive Order does not apply to actions delegated by Federal agencies to states, it has limited applicability in SMCRA permitting actions in all of the study area states except Tennessee. The Tennessee Federal program under SMCRA complies with the Executive Order. Provisions of the COE/FWS and EPA/FWS MOUs implementing this Executive Order would apply in all of the states within the study area. No change to the DPEIS is necessary.

Comments:

Recent research indicates that as landscapes fall below a threshold of about 82% forest cover, the ecological integrity of the forest community becomes increasingly compromised. Projected impacts from MTM/VF alone will bring the study area forest cover close to this threshold and will cause some landscape-level areas within this larger area to fall well below this threshold.

The projected level of forested habitat loss constitutes a significant negative impact for the entire mature forest suite of birds, especially for Cerulean Warbler, the forest species of highest concern in this area. Other species affected include: ridgetops – yellow-throated warbler, Eastern wood pewee, scarlet tanager, ovenbird, wood thrush; mature mixed-mesophytic forest along headwater streams (“coves”) — Louisiana waterthrush, worm-eating warbler, Kentucky warbler, Acadian flycatcher, wood thrush.

DPEIS cumulative impact figures suggest a massive and permanent impact within the PEIS study area on the entire suite of priority mature forest birds (cerulean warbler, Louisiana waterthrush, worm-eating warbler, Kentucky warbler, wood thrush, yellow-throated vireo, Acadian flycatcher) due to estimated forest loss of 11.5% of the total forest cover in the study area.

According to Partners In Flight bird conservation plans, mature forest birds are a high conservation priority within the PEIS study area, whereas grassland birds *are not. In addition, the creation of poor quality, early-successional habitats that may be suitable for some shrub-nesting species does not justify, or in any way compensate, the removal and fragmentation of extensive mature forest areas within the PEIS study area.*

Response:

The cumulative impacts to forest habitats identified in the DPEIS lend emphasis to the need for reforestation efforts such as those proposed in Action 13 in the preferred alternative. This information could be considered by the regulatory agencies when evaluating projects, with a view toward minimizing future impacts.

Comments:

The statement on page III.F-11 conflicts with the findings of the Cumulative Impact Study (CIS) and the terrestrial technical studies. The CIS found that abundant habitat will continue to exist in the region even when mining disturbance is assumed to have the greatest impact (no reforestation) and mining is considered along with all other human activities. According to the CIS, the area will remain 87.5% forested. The Wood and Edwards terrestrial technical study found that forest-interior species were present in the fragmented forest area created by mining. As noted in a subsequent paragraph in this same section, the majority of species have the same abundance in the fragmented forest as the intact forest.

The DPEIS has already acknowledged that existing rules and regulations imposed by SMCRA are the biggest factors preventing reforestation. With the renewed emphasis on reforestation and tree growth that will result from the PEIS alternatives, it is reasonable to assume that tree reclamation will increase in the study area. However, if tree reclamation was not advocated in the PEIS alternatives, scientific research indicates that these grassland and shrub/pole habitats are supporting a healthy and diverse terrestrial community with species of both forest-interior and grasslands being recorded on reclaimed areas.

Some forest edge and grassland species (certain reptiles, birds, mammals, raptors, etc.) are positively impacted by the terrestrial habitat diversity created by MTM. [page II.C-75] The PEIS documents that there has been an increase in the abundance of edge and grassland bird species at reclaimed MTM sites. [page III.F-7]

On page III.F-8, second paragraph – "Some argue that mountaintop mining has the potential to negatively impact, in particular neotropical migrants, through direct loss and fragmentation of mature forest habitats. Forest interior species…have significantly higher populations (at least one year of the two-year study) in intact forests than fragmented forests. Furthermore, cerulean warblers…are more likely to be found in a forest area as distance from a mine increases. These data suggest that forest-interior species are negatively impacted by mountaintop mining through direct loss of forest habitat and fragmentation of *the terrestrial environment." The data presented in the DPEIS technical studies DO NOT support such a conclusion. Higher populations of forest interior species in intact forests versus fragmented forest in one year of a two-year study are far from conclusive.*

Response:

The Wood and Edwards study found that four forest-interior species (Acadian flycatcher, scarlet tanager, blue-headed vireo, and ovenbird) were less abundant in fragmented habitat than intact forest. The MTM/VF study area is the core North American breeding area for a number of forest interior species; the core breeding area for the grassland species using the reclaimed mines does not include the study area.

Additional work by Weakland and Wood (2002) found that cerulean warblers are negatively affected by mountaintop mining from loss of forested habitat, particularly ridgetops, and by fragmentation. The Southern Environmental Law Center petitioned the FWS to list the cerulean warbler as threatened and to designate critical habitat. The FWS's 90-day finding identified mountaintop mining as one of the threats to this species, and noted that "unfortunately, the area of the country with the highest density of ceruleans is also in a coal-mining region where mountaintop removal mining is practiced." (See 67 FR65083 (Oct 23, 2002)).

The agencies recognize that this study was of limited scope. The agencies considered it but did not rely on it in the analysis of the alternatives. Page IV.D-4 provides additional information on this topic.

Comments:

No studies on edge bird populations were conducted in Virginia where the typical permit size is smaller than sites used in the study. Therefore, the conclusions in the report may not be applicable to Virginia.

The DPEIS gives the reader the impression that all surface mines leave huge tracts of grasslands. This is not true in Virginia. More than 85% of all mined land in Virginia is returned to forestland.

page III.F-12 Appalachian Forest Communities — characterizes reclaimed mined lands in the study area as, "…often limited in topographic relief, devoid of flowing water, and most commonly dominated by erosion-controlling, herbaceous communities". This characterization is not accurate for reclaimed mine lands in Southwest Virginia. Eighty five percent of reclaimed mined lands in Virginia are returned to forests. Most reclaimed mined lands in Virginia are returned to the approximate original contour including re-establishing drainage patterns.

Many of the generalizations made about the study area do not or should not apply to Virginia's coalfields. It is clear that many of the referenced studies included in the Appendix and narrative in Chapter III do not include Virginia. It's unclear and, most readers/reviewers will probably be unsure, if Virginia's seven coalfield counties were part of the areas actually studied for the PEIS.

Response:

This PEIS evaluates programmatic alternatives that, if implemented, would be applicable to individual mountaintop mining operations and conditions in Appalachia. The DPEIS provided an opportunity to collect updated data on a range of surface mining impacts and led the agencies to prepare and evaluate the alternatives and actions presented. However, analysis of the alternatives was not dependent on representative data from all locations within the study area. The PEIS focuses on the similarities of the Appalachian coalfield states' programs and affected environments, rather than their unique differences. Any further action supported by this PEIS would involve further coordination with and participation by the appropriate state agencies and would take into account the applicable state laws, regulations, mining methods, and unique environmental conditions.

Before implementing many of the individual actions considered as part of the alternatives, there will be a need for the collection and analysis of additional scientific data and if appropriate, additional public participation and NEPA analysis.

5.2.8 Category: Threatened & Endangered, Candidate, and Species of Concern

This category is a grouping of comments related to Federal Threatened, Endangered, or Candidate species and state listed species. This category also includes comments on the regulatory program interaction with the Endangered Species Act. This category corresponds to category 8 in the *Public Comment Compendium* document.

Comments:

The DPEIS underestimates impacts on threatened and endangered species.

The public should have the opportunity to comment on the biological assessment before implementing it.

Response:

Limited evaluation of threatened and endangered (T&E) species was provided in the DPEIS. The agencies noted that a more detailed evaluation was anticipated to be provided in a Biological Assessment (BA) pursuant to the Endangered Species Act (ESA). Pending compliance with the ESA, the DPEIS indicated that there could be impacts to threatened and endangered species [see page II.C-90]. However, in the process of making a determination of effects, the agencies determined that there would be no effects on T&E species as a result of the preferred alternative. The agencies reached this conclusion because the DPEIS was programmatic and identified actions in the alternatives for consideration in concept.

Each of the Alternatives is made up of a series of individual actions listed in Table II.C.1, in Section II.C. Table II.B-2 describes the distinctions among the alternatives. The list of T & E species known to inhabit the study area is found in Appendix F. CWA and SMCRA regulatory agencies must either consult or coordinate with the FWS, as appropriate, to ensure the protection of endangered or threatened species and their critical habitats as determined under the ESA (see Section II.C.11 (page II.C-92).

If the actions in any of the alternatives were fully developed and implemented, the environmental benefits could include using and/or developing best scientific methodologies. Each of the action alternatives would lead to establishing common criteria and science-based methods for determining baselines, impacts, and mitigation requirements. Monitoring information could be used to identify and evaluate T & E listed species habitats; stream reaches supporting naturally diverse and high quality aquatic populations, sole or principal drinking water source aquifers; or other specially protected areas. By inclusion of a habitat quality evaluation, as well as CWA Section 404 (b)(1) Guidelines analysis (or its equivalent) in all three action alternatives, the least-damaging practicable alternative for the placement of fill in waters of the U. S. may be chosen.

Improved communications and the use of a designated regulatory authority as a focal point for initial data collection should result in better cataloguing of T & E species and would address this issue at the earliest possible stages of permit review. If T & E species are present, measures required to protect them will be required.

Under Action 17, the agencies would identify and implement program changes, as necessary and appropriate, to ensure that the proposed action is carried out in full compliance with the ESA. To the extent necessary to assure compliance with the ESA, this action envisions development of additional species-specific procedures and protective measures to further minimize adverse effects for listed species that occur in the steep slope mining region, beyond those requirements outlined in the 1996 Biological Opinion (BO). These actions could include survey protocol, monitoring requirements (e.g., water quality and quantity), protective restriction (e.g., buffer zones, seasonal restriction), and prohibitions (e.g., operations that would jeopardize the species). These species-specific procedures and protective measures can be used to develop area-wide plans that would assist mining companies in preparing their mining plans. For example, baseline information on species presence, standardized protective measures, and monitoring of potential cumulative impacts can be developed on a regional or watershed scale that would assist reviews of individual projects.

Each of the actions in the action alternatives in the PEIS calls for developing certain potential measures to minimize impacts from MTM/VF activities that now are conceptual, preliminary, and undeveloped. The agencies have not yet determined the specific techniques or technologies that would be employed, the specific objectives and measures that would apply, or the products, practices, or standards that would result. Because parameters and directions for these actions have not been developed, evaluation of the impacts of the actions on T & E species and their designated critical habitats is not yet feasible. Until development of any action would occur, there would be no effects from the possible action on specific T & E species and their critical habitats.

Comments:

The cumulative effects of MTM/VF could negatively impact other species of concern, including state-listed species. Conservation of these rare species will in *part depend on whether they are given sufficient consideration when planning for future MTM/VF locations. The commenter requests that the DPEIS give consideration to all state-listed plants and animals, regardless if such species are likely to become Federally-listed.*

Specific species, specifically state-listed species, have not been addressed in the DPEIS.

Response:

SMCRA and state laws require that consideration of state-listed species takes place on a permit-by-permit basis and such consideration is therefore not included in this programmatic EIS.

Comments:

The DPEIS fails to discuss or inadequately discusses the impacts of MTM/VF on migratory birds and mature forest birds within the PEIS study area (Cerulean Warbler, Louisiana Waterthrush, Worm-eating Warbler, Kentucky Warbler, Wood Thrush, Yellow-throated Vireo) from the projected loss of over 380,000 acres of high quality forest in the next 10 years.

The DPEIS ignores available scientific data showing higher bird densities and higher potential losses from mining impacts. Important Cerulean Warbler research findings by Weakland and Wood were not included in the DPEIS, even though it was provided to DPEIS preparers.

Response:

The DPEIS discusses impacts to migratory and mature-forest birds at Section IV.D.1.a and acknowledges potential impacts to these species through loss of habitat.

Additional work by Weakland and Wood (2002) found that cerulean warblers are negatively affected by mountaintop mining from loss of forested habitat, particularly ridgetops, and by fragmentation. Information on the Weakland and Wood findings has been added to the errata section of this document.

Comments:

Action 17 is unnecessary. The most recent biological opinion issued by FWS says that: "…surface coal mining conducted in accordance with properly implemented state and Federal regulatory programs under SMCRA would not be likely to jeopardize the continued existence of listed species or species proposed to be listed, or result in the destruction or adverse modification of designated or proposed critical habitats." Endangered species issues can be adequately addressed on a permit-by-permit basis under existing regulations.

Response:

The commenter is referred to the DPEIS, Section II.C [page II.C-90], for a description of the regulatory program interaction with the Endangered Species Act, and the need for Action 17.

Comments:

On page II.C-90, Threatened and Endangered Species — The statements and assumptions of the DPEIS fail to consider the scope of the activities in question. The Cumulative Impact Study (CIS) determined that mining affects only a small portion of the study area, which will remain dominated by densely forested areas. The same technical study found that headwater streams comprise 60% of all streams in the region and that mining has the potential to impact only 4.10% of these streams. The commenter believes that, in preparing the Biological Opinion (BO), the agencies MUST consider these factors because it is very apparent that neither mining nor any human activity will result in massive elimination of existing fish and wildlife habitat.

The commenter believes that the BO, to be adequate, must also consider the positive effects of mining-created habitats for certain species of wildlife. The DPEIS terrestrial studies failed to show that current mining and reclamation practices were adversely impacting existing wildlife assemblages because species thought to be rare and declining in the study region were found in reclaimed areas. These unexpected species are targeted for conservation efforts.

The commenter states that at least one of the technical studies went to great lengths to ignore these terrestrial gains. The same mistakes cannot be repeated in the BO if it is to adequately protect threatened and endangered species.

Response:

The commenter is referred to the PEIS, Section II.C.11 [page II.C-90], which describes the ESA compliance process. Pending compliance with the ESA, the DPEIS indicated that there could be impacts to threatened and endangered species. However, in the process of making a determination of effects, the agencies determined that there would be no effects on T&E species as a result of the preferred alternative. The agencies reached this conclusion because the DPEIS was programmatic and identified actions in the alternatives for consideration in concept. Further development of the individual actions would define them sufficiently to allow evaluation of their effects on T&E species. At that time, any additional required compliance with the ESA would be carried out as appropriate.

5.2.9 Category: Cumulative Impacts

This category is a grouping of comments related to the cumulative impacts analysis in the DPEIS. This category includes comments on the adequacy of the cumulative impact analysis on social, economic, cultural, emotional and spiritual health. This category corresponds to Category 9 in the *Public Comment Compendium* document.

Comments:

The DPEIS cumulative impact analysis is inadequate, and called for the FPEIS to revise the evaluation of cumulative impacts on socio-economic factors and cultural, emotional, physical, and spiritual health. A "partial" cultural study *performed by an ethnographer at the University of Pennsylvania is available. A 2003 economic report to the Governor of Tennessee illustrating that coal mining influence on the Tennessee economy is small when compared to other business.*

Response:

Because this "programmatic" DPEIS evaluates broad Federal actions, it proposes only the direction for future actions. In complying with Section 102 of NEPA, the DPEIS evaluated cumulative impacts in a general manner consistent with other programmatic NEPA documents. The agencies recognize the importance of socio-economic factors and intangible values such as cultural and spiritual health. Because these issues are intangible and complex, there are many different methods for evaluating them. The commenters suggested alternative methods for analyzing the impacts on these intangible factors. The information provided by the commenters regarding socio-economic conditions and communities was considered. However, the agencies' approach was consistent with Section 102 of NEPA, which requires that these values be given "appropriate" consideration. Emphasis was placed on analysis of *those* impacts and issues identified as most important in the scoping process. For example, see the issues identified in Section I.G and Section II.A.3 of the PEIS. The DPEIS describes the baseline socioeconomic conditions in Chapter III and describes the consequences of the alternatives for these socioeconomic conditions in Chapter IV.

Comments:

Cumulative impacts were not addressed in the DPEIS in sufficient detail. Commenters cited a need for more expansive, site-specific information and analysis on economics, cultural, and environmental consequences.

A commenter questioned whether sections of the DPEIS relative to Tennessee data on active and abandoned mining, coal reserves, parks, newly discovered plants and animals, wildlife management areas, economic conditions, climatology, population, land use, and transportation were complete or up-to-date.

Another commenter suggested that the inadequacy of cumulative impact analysis should have been overcome by commissioning the National Academies of Science and Engineering for independent review.

The PEIS should be expanded to include cumulative impacts of non-metallic mineral operations.

Response:

NEPA analyses of cumulative impacts for a programmatic EIS are, by their very nature, general. The CEQ regulations and guidelines on preparing NEPA documents and case law clearly indicate that the level of detail required of a site-specific project proposal is not necessary for a broad programmatic EIS. This NEPA document was not intended to supplant the site-specific data collection and analyses that occur prior to mining authorization.

The cumulative impact analysis data collection and evaluation within this document is commensurate with or more expansive than similar analysis in other programmatic EIS documents. Non-metal mining, including quarries and gravel pits, was included in the Landscape Scale Cumulative Impact Study of Mountaintop Mining Operations (Appendix I). The stated purpose of the PEIS, in terms with the *Bragg* settlement agreement, was limited to steep-slope surface coal mining in Appalachian where excess spoil disposal occurs. Commissioning the National Academies to conduct such analyses is within the discretion of Federal agencies, but not mandated. The agencies explored Academy work for some portions of the PEIS work, but concluded that this was not a feasible option.

Comments:

There is no systematic evaluation in the DPEIS of the cumulative impacts of the loss of headwater streams. This is not mentioned in the Executive Summary or in the alternatives and evaluation sections.

Response:

An adequate level of cumulative impact assessment was made by modeling the landscape to determine the total length of stream channels in the study area and by using past permit information to determine the rate of impact for the past ten years. The DPEIS has projected into the future by assuming that the rate of coal mining will continue at the level it has in the past ten years (although factors such as the price of coal, competitiveness, availability of coal reserves, difficulty of mining affect the rate) and extrapolating that into the future.

Comments:

Only one technical study looked at cumulative aquatic impacts and it showed that the effects of valley fills were additive.

Response:

The agencies believe the commenter is referring to the Ecological Assessment of Streams in the Coal Mining Region of West Virginia Using Data Collected by the U.S. EPA and Environmental Consulting Firm (Fulk *et al*., Feb, 2003; Appendix D, Part 2). A number of limitations were recognized including the following: a small number of sample sites, less than a full year of data, omission of other types of fill impacts such as highways and commercial development, and difficulties in attributing cause and effect relationships for cumulative impacts. In its analysis, the study did not consider the number or age of fills to investigate whether water quality impacts were any of the following: (1) seasonal; (2) dependent on other factors such as rainfall; or (3) decreased over time and/or distance from the fills. The agencies considered these limitations when evaluating the aquatic environment. Therefore, the one study was not used as the basis for making broad assumptions about the impacts of valley fills on downstream aquatic functions.

5.2.10 Category: Social Values

This category is a grouping of comments related to environmental justice, community, socio-economic, demographic, quality of life, aesthetic and cultural concerns. This category corresponds to category 10 in the *Public Comment Compendium* document.

Comments:

The DPEIS does not accurately or adequately portray socio-economic, demographic, and other types of social/cultural data or community resources particularly for VA, TN, and KY.

Response:

The DPEIS only generally describes such data. Because this is a programmatic EIS, implementation of the individual actions under the preferred alternative would, as appropriate, include APA and NEPA procedures that would require detailed information from affected states and take into account local and unique conditions. Also it must be pointed out that a programmatic NEPA document such as this is, by its very nature, general. CEQ regulations and guidelines on preparing NEPA documents clearly indicate that the level of detail of a site-specific project proposal is not required for a broad programmatic EIS. This PEIS document evaluates impacts in a general manner consistent with other programmatic NEPA documents.

Comments:

The 2003 DPEIS fails to comply with Executive Order 12898 (Environmental Justice) and did not discuss environmental justice concerns sufficiently. This is another blatant lack of regard for low-income populations and their disproportionate share of the impacts. This population needs to be addressed in any PEIS regarding mountaintop mining and valley fills, solely because they are the most vulnerable to governmental actions in this region.

Response:

The agencies made a significant effort to identify and reach out to EJ communities (see Sections III.P through T and IV.J). A significant portion of the PEIS study area includes economically disadvantaged communities. There appears to be a potential for ecological, environmental, economic, heritage, and cultural impacts that could potentially represent risks to the communities in question. Just four of the 69 study area counties had a per capita income exceeding its state average per capita income in 1990. Therefore, the outreach the agencies conducted to reach residents of the study area was effectively outreach to members of the EJ community. Outreach efforts included mailing letters announcing public meetings to approximately 2,500 citizens in the Appalachian coalfield area. In addition, the agencies mailed additional letters requesting comments on the scope of the PEIS and published newspaper notices requesting comments from all of the states in the study area. The agencies received and considered over 700 scoping comments, and approximately 4,700 comments on the DPEIS from the four states within the study area. In addition, the agencies anticipated that to some significant extent, citizen groups whose participation in the PEIS was actively sought would actively and effectively present EJ community concerns (see page I-12).

Although not specifically identified as EJ concerns, issues of central concern to EJ communities were discussed throughout the DPEIS. For example, EJ was addressed in Sections II.A.3.f, IV.H, IV.I, and IV.K. In light of the fact that this is a programmatic EIS, the actions contemplated have not been sufficiently developed to allow a mores specific evaluation of impacts on the EJ community. That evaluation will have to await further development of the actions.

Comments:

The DPEIS fails to adequately address the cultural concerns expressed during scoping and further study is recommended (e.g., wild ginseng habitat loss and associated economic impact). The DPEIS begins to address cultural resources and their significance but it does not clarify the true cost of the loss of these resources relative to the short term gains from MTM.

Response:

Appalachian coalfield residents do have a unique social and cultural connection to the natural environment. For coalfield residents, the quality of the natural environment is important both as a source of income and an integral element of Appalachian culture. Sections III.U.5 and III.U.6 present an overview of the relationship between the natural environment, Appalachian culture, and coal mining. The cumulative effects of mining may ultimately affect the human environment in ways such as land use and potential development, as described in Section III.S; historic and archaeological resources, as described in Section III.T; and the cultural, social, and economic importance of existing landscape and environmental quality, as described in Section III.U. All three action alternatives would facilitate a better understanding by the public of the regulatory process and therefore facilitate their input regarding social concerns that should be factored in permit decision-making. This improved efficiency would result in mining companies having more predictability in their planning processes, resulting in reduced costs and time.

Comments:

The language of the PEIS favors the coal mining industry and ultimately supports the goals of the coal industry over other options.

Response:

The agencies identified some assertions and allegations that reflect differences in opinions or preferred outcomes of commenters. Some of those comments reflected different interpretations of study conclusions or DPEIS analyses. In many cases, the commenters provided no clarification or additional data to support their assertions. The agencies reviewed these comments but did not agree with the allegations of bias. The bases for the analyses and conclusions for the PEIS are stated throughout the PEIS and including these responses.

Comments:

Many sites may have historical significance such as portions of Blair Mountain and the Stanley family on Kayford Mountain. An assessment of cultural and historic losses is needed.

Response:

If MTM/VF projects may impact historic properties, the projects are coordinated with the State Historic Preservation Office (SHPO), which operates to protect historic and cultural resources consistent with the National Historic Preservation Act (NHPA). The mission of the SHPO is to encourage, inform, support, and participate in the efforts of people of the state to identify, recognize, preserve and protect prehistoric and historic structures, objects and sites [page IV.G-2].

Comments:

What are the actual costs to the communities and people that suffer the effects of MTM/VF? This mining affects the very poor, the powerless and oppressed people. Economic development only reaches 6% of the destroyed mountains.

Some commenters requested the agencies identify and/or provide detailed, additional information, history, data, and examples of specific site plans, or permit decisions that support statements, conclusions and/or positions in the DPEIS. Other commenters requested an indication of where, in the DPEIS, explanations or specific information may be found.

Response:

Those comments were considered but the information requested was either more specific than is appropriate for a programmatic document or currently exists in Sections III.U and IV.H of the DPEIS.

Comments:

Coal companies should not be permitted to destroy local communities in the process of MTM/VF mining. Community residents with homes and farms should be protected from the consequences of such damage. Under current law, a homeowner can pursue a damage claim in court. The practical problem is the cost of hiring attorneys and the litigation costs in hiring expert witnesses.

Response:

The impacts of MTM/VF on communities are analyzed throughout Chapters III and IV. Concerns about the costs of pursuing remedies under statutes other than the SMCRA and CWA are outside the scope of this PEIS.

Comments:

The demographic realities of the study area stress the economic and social importance of the coal industry. Coal mining activity creates substantial economic activity through high-paying wages for coal miners and demand for goods and service related directly to coal extraction. The ripple effect of this activity is tremendous and mining is the only economic driving force in a majority of the study area. However, mining will never occur on a scale large enough to eliminate or even substantially impact the rich culture and history of Central Appalachia.

Response:

Coal mining practices have profoundly affected the communities and residents of the Appalachian coalfields since coal mining first commenced in the region. Sections III.U.1. through III.U.4. provide an overview of the past and current interaction between the coal mining industry and the residents of Appalachia. A decline in the physical state of the community may affect the economic status of local residents. Coal companies frequently built and maintained local infrastructure, from housing to plumbing and even churches, in the coal towns of Appalachia in varying degrees of quality. Today, many coalfield communities not only receive revenue from taxes on coal property and employment, but also donations of money, land, and company equipment to support civic organizations. [page IV.G-2]

Setting public policy to balance environmental protection and energy needs is not a simple matter for Congress, the agencies implementing Federal law, state legislatures, or state agencies implementing state or Federal law. Normal supply and demand principles govern the energy market. For instance, the type of coal needed to comply with the Clean Air Act also influences demand. If a certain type of coal is required to meet clean air requirements and is more expensive to mine, then the cost of electricity to consumers will go up. [page IV.I-1]

5.2.11 Category: Economic Values

This category is a grouping of comments related to adverse economic impacts of new regulations to restrict mining, economic benefits of mining and the economic analysis. This category also includes comments on property values. This category corresponds to category 11 in the *Public Comment Compendium* document.

Comments:

The coal industry and, in turn, the coalfield communities will suffer with the inclusion in the PEIS of alternatives or actions that create more stringent regulations.

Alternatives and actions in the PEIS must consider the benefits of coal mining (i.e. severance taxes, electricity, employment, etc.) and the adverse impacts that any new regulations to restrict mining would have on everyone in the coal fields. A long-term economic study should be conducted about "everything this is costing us," not just the economic benefits of coal mining. The economic study indicated that even under the most restrictive MTM scenarios, little adverse economic impact would result.

Response:

The agencies do not agree that the mere act of including or considering alternatives in a PEIS can cause an adverse impact. As indicated in Sections III.Q and IV.I.2 of the DPEIS the economic costs of regulatory compliance are not significantly different among the alternatives; because there were no alternatives carried forward that would adopt new regulations to restrict mining. Rather, the alternatives emphasized other means to reduce the environmental impacts of mining. These two chapters also discuss the economic benefits of coal mining operations to an area. However the economic studies did show a direct correlation between fill size and shifts in production due to increased mining costs. Additional information on the economic studies conducted can be found in Appendix G.

Comments:

A significant failure of the DPEIS is that it fails to analyze in a meaningful way the economic impacts of mining restrictions. The agencies rejected a 2-phase economic study that had been prepared specifically for this DPEIS that addressed the economic impact based upon differing fill restrictions alternatives. Since the fill restriction alternatives were not carried forward in the DPEIS, the economic studies were described as no longer being essential for an analysis of the alternatives developed.

Response:

The economic studies were not rejected. The studies have been provided in the DPEIS. However, the economic reports were not essential for the full development and analysis of the alternatives selected for inclusion in the DPEIS.

Comments:

The Phase I and Phase II economic studies are seriously flawed and many parts of the DPEIS are not supported by accurate, fact-based studies. Conclusions drawn in the DPEIS and any actions taken in response to these conclusions may be considered arbitrary and capricious. Any actions taken as a result of this PEIS need to be justified by separate, accurate, fact-based studies and not rely on the information in the DPEIS.

The effects of the 250-acre threshold require more explanation in the PEIS as the reader is left with the impression that the limit is impact-free, which it clearly is not: reserve bases are being reduced and the projected life of particular mine sites are being diminished with coincident reductions in employment, state tax collections etc.

Response:

In the cover sheet to Appendix G, the agencies indicated that the site-specific results of the Phase I and II economic studies have limitations and should not be relied on as representative of potential future mining and fill areas or as precise with respect to production change estimates. It was recognized in Section IV.I.2 of the DPEIS that implementation of any future agency action (e.g. more stringent fill minimization regulations) following the FPEIS would, as appropriate, include independent NEPA, legal and regulatory analysis of the relevant economic consequences of any such action.

No further explanation of the effects of the 250 acre threshold alternative is required for the reasons set out in Section II.D. This alternative was not carried forward.

Comments:

The PEIS should address the impact any decrease in mining would have on the Federal Abandoned Mined Land program and the UMWA Combined Benefit

Funds when looking at the potential loss of mining as a result of the PEIS alternatives.

DPEIS fails to consider the monetary value of eco-system services to the current and future economy.

Response:

A programmatic NEPA document such as this is, by its very nature, general. CEQ regulations and guidelines on preparing NEPA documents clearly indicate that the level of detail of a site-specific project proposal is not necessary for a broad programmatic EIS. This PEIS document evaluates impacts in a general manner consistent with other programmatic NEPA documents.

Comments:

Agencies have not analyzed the availability of coal resources outside of Appalachia. Therefore the economic analysis is not adequate.

Response:

The agencies do not agree with the commenter's assertion that the agencies did not consider the availability of coal resources outside of Appalachia, See Sections IV.I.1-2.

Comments:

Economic diversification and social stabilization (by relocating flood prone communities) are real possibilities only if alternative post-mining land uses, other than reforestation, are preserved in the regulatory program.

Response:

This comment appears to refer to Action 14 (page II.C-83). Changes in the current regulatory program, such as requiring reforestation as the only post mining land use, would require Congressional action. Such legislation may provide exceptions to reforestation if another land use would provide greater environmental benefits.

Comments:

The FPEIS should not focus on the ability of mitigation to economically discourage fill placement, since fill minimization is already addressed through SMCRA and the CWA Section 404(b)(1) Guidelines.

The reality of increased and what appears to be punitive mitigation requirements (e.g. conservation easements) will not result in further minimized fills, it will only add yet another economic constraint on the ability to mine coal in this region because the physical and economic recoverability of coal reserves is directly correlated to the amount of fill space available.

Response:

It is correct that fill minimization is already addressed in SMCRA and the CWA Section 404(b)(1) Guidelines. The agencies, however, recognize that compensatory mitigation has an economic cost and may discourage disturbing or filling stream segments. Conservation easements are a mitigation option and not always required. Compensatory mitigation is not punitive but is designed to offset aquatic resource impacts.

Comments:

The analysis of the effects on property values is inadequate. The PEIS should assess property values in communities both before and after mountaintop removal operations begin. Property values have decreased dramatically due to the adverse effects of surface mining. In addition, commenters expressed frustrations about losing what they have worked hard to build, and being unable to sell their property because it is unwanted in its current condition.

Response:

This PEIS addressed economic issues at a programmatic level. Economic issues related to site-specific property values before and after start of mining are outside the scope of this PEIS.

Comments:

Comments were offered detailing the "takings" implication of forbidding or severely curtailing mountaintop mining operations.

Response:

Alternatives in the PEIS that would, on a programmatic level, impose stricter limits on mountaintop mining were not carried forward for detailed analysis.

5.2.12 Category: Government Efficiency

This category is a grouping of comments related to streamlining the permitting process. This category corresponds to category 12 in the *Public Comment Compendium* document.

Comments:

States should be encouraged to assume the CWA Section 404 program, and be provided with adequate funding.

Response:

State assumption of the CWA Section 404 program is outside the scope of the PEIS.

Comments:

Valley fills should be evaluated under CWA Section 404 as individual permits. Fees should be increased to hire more personnel to do additional studies on cumulative aquatic impacts.

Response:

Requiring individual permits for most MTM/VF activities is considered in Alternative 1. The COE may further study cumulative aquatic impacts in cooperation with other agencies when developing actions under Alternative 2, the preferred alternative (see Action 12, page II.C-69).

Comments:

Although supporting the need for clear, concise definitions and procedures for issues such as jurisdictional waters, the DPEIS fails to develop such issues/terms.

Response:

There are currently different definitions of jurisdictional waters for CWA, SMCRA and state law as administered by various state and Federal agencies. There is an action in the preferred alternative in the DPEIS that proposes that the Federal and/or state agencies will develop guidance or policies, or institute rule-making for consistent definitions of stream characteristics as well as field methods for delineating those characteristics. [Section II.C.2.b]

5.2.13 Category: Excess Spoil

This category is a grouping of comments related to excess spoil, construction of fills, fill minimization and fill stability. This category corresponds to category 13 in the *Public Comment Compendium* document.

Comments:

In assuming under all the alternatives that excess spoil can be placed in streams, the PEIS makes no provision for analysis of the benefits of maintaining the current level of protection afforded by the SBZ rule (i.e., precluding placement of excess spoil in streams).

Response:

The PEIS considered precluding placement of valley fills in waters of the U.S. but that alternative was not carried forward for detailed analysis (see page II.D-8). The SBZ rule is the subject of a separate nationwide rulemaking and nationwide EIS [see proposed rulemaking notice: 69 FR1035 (Jan 7, 2004); and Notice of Intent to Prepare an EIS: 70 FR35112 (June 16, 2005)].

Comments:

A commenter recommended that more information be provided in Section III. K. 4 (Trends in Watershed Size), as to the usefulness of the excess spoil disposal trend analysis and what impacts would be specifically anticipated.

Response:

Sections III.K.2 through 5 provide valuable information to assist in characterizing the extent to which valley fills have affected the environment during the period of 1985-2001. Impacts that are associated with the alternatives that were carried forward are analyzed and described in Chapter IV.

Comments:

Excess spoil fills such as valley fills and head-of-hollow fills are integral to underground mining in Appalachia and should be considered in the analysis presented in the PEIS.

Response:

On page 1 of the Executive Summary and in Section I.C of the PEIS, the agencies clearly indicate that underground mining activities are considered to be beyond the scope of this document.

Comments:

Coal extraction methods require the construction of head of hollow fills and valley fills in coal mining operations in the study area. Using valley and head of hollow fills in this region is absolutely necessary, because when mining is conducted in steep-slope areas such as Appalachia, the volume of the spoil material is significantly greater than the volume of the overburden excavated from its original geological location. This is true whether the mining methods are mountaintop mining, contour mining, or even, in many instances, when creating the necessary surface area to begin and support an underground mine.

Response:

The agencies described how excess spoil is generated by surface mining operations in Appalachia in the PEIS at Sections III.K.1.a and III.K.6. The agencies in the PEIS describe how existing regulatory programs require operators to minimize the amount of excess spoil consistent with the authorized post-mining land use, and limit the placement of this spoil in waters of the U.S. (see Section II.C.5).

Comments:

A concept on page IV.I-4 related to mitigation and reduced fill sizes should properly acknowledge that operations assure fill minimization by satisfying the AOC mandate of SMCRA and the CWA Section 404(b)(1) analysis. The cost of any required compensatory mitigation would reduce the economic or practical viability of the operation.

Response:

Under the CWA Section 404(b)(1) guidelines, applicants are required to first avoid, then minimize, impacts to waters of the U.S. Any remaining unavoidable impacts to waters of the U.S. must be replaced through "compensatory" mitigation. During the permitting process, the COE generally does not consider the economic impact of such mitigation costs to the applicant on the viability of the project.

Comments:

The statement concerning long-term valley fill stability in Section III.K.1 is misleading and it should either be removed from the FPEIS or revised to reflect the findings of the PEIS Valley Fill Stability technical study.

Response:

The agencies do not agree that the statement concerning long-term valley fill stability in Section III.K.1 is misleading. In the introduction of Section III.K, the document states, "there is also concern regarding long-term fill stability." The statement simply acknowledges that, as this document was being developed, there were concerns expressed related to stability of valley fills.

As discussed in Section III.K.1.c, the lead agencies initiated a study of this issue to determine if the issue was one that would rise to the level of significance within the context of NEPA, and thus require action(s) to be incorporated within the alternatives considered. The study found that there were only a very small percentage of fills that had experienced stability problems. In Section II.A.3.d, the agencies explain their rationale for not developing action(s) for this issue.

Comments:

Very isolated opportunities may exist for the placement of generated spoil on adjacent flat areas such as AML benches. However, these occurrences would be so rare and dependent on such a wide range of factors that they deserve no mention as a reasonable alternative to valley fill construction. No substantial amount of coal could ever be produced from an operation that was dependent on an AML area for spoil placement.

Any reference to these two surface mining techniques should be deleted from statements in Section IV.I.2.

Response:

As explained in Section IV.I.2 of the PEIS, storage of excess spoil materials on abandoned mine benches, reclaimed mine sites, or active mining areas provides limited opportunities for excess spoil storage that may reduce either the need for or the size of valley fills. As such, these possible alternatives must be evaluated as part of the various regulatory permit application processes. It is also worth noting that as discussed in Section III.K.3, between 1985 and 2001, a number of permits were issued in the study area states that did not include valley fills. Alternative methods of excess spoil disposal other than valley fills were no doubt part of the reasons that permits without valley fills were issued. As such, these possible alternatives must be considered.

5.2.14 Category: Stream Habitat and Aquatic Functions

This category is a grouping of comments related to mitigation of stream habitat and aquatic function loss. This category includes comments on functional stream assessments. This category corresponds to Category 14 in the *Public Comment Compendium* document.

Comments:

The DPEIS fails to analyze the effectiveness of mitigation for stream loss.

Response:

Future actions under the preferred alternative would include monitoring and cumulative impact analyses of stream impacts.

Comments:

The COE does not have the authority nor has it explained the recent shift in policy to require no net loss of stream length or functions.

Response:

The COE national mitigation policy is that all impacts to waters of the United States, not just wetlands, generally require compensatory mitigation. This policy has been in existence since 2001 and was required by many COE districts prior to that time. In 2001, Regulatory Guidance Letter 01-1 specifically discussed the need for compensatory mitigation for streams. Regulatory Guidance Letter 02-2, which superceded the previous guidance, reinforced this policy. In addition, when the nationwide permits were reauthorized on January 15, 2002, compensatory mitigation for stream impacts was included in General Condition 19 on mitigation and in the definition of compensatory mitigation. The rule-making issuing the nationwide permits went through the Administrative Procedures Act as required. Conservation easements are encouraged, where possible.

Comments:

The DPEIS fails to acknowledge the fact that proposed COE policy changes/procedures would extend far beyond mining into areas such as highway construction, etc.

Response:

The existing COE policy is to replace lost functions for all aquatic resource impacts and is outside the scope of this PEIS.

Comments:

The DPEIS fails to present any methodology for performing functional stream assessments. Functional assessments should be presented for public review. They may be expensive, scientifically unproven and do not accurately measure lost stream functions.

Response:

Stream assessments are developed using the best data available to identify indicators of aquatic functions. The COE makes any methodology for performing functional stream assessments available to the public and accepts comments and new data on a continuing basis. The commenter is encouraged to provide this and similar comments to the COE.

5.2.15 Category: Air Quality

This category is a grouping of comments related to air quality, potential health risks from mining, blasting dust and fumes, and fugitive dust. This category corresponds to Category 15 in the *Public Comment Compendium* document.

Comments:

The generation and regulation of fugitive dust and other pollutants from blasting and the potential health risks associated with these pollutants need additional study.

Response:

The agencies do not agree that the PEIS needs to contain additional studies on this issue. The following sections of the draft and final PEIS considered these impacts:

Section III.V and Appendix G contain a recent study conducted by West Virginia University on dust and fumes generated from blasting in the Appalachian region.

Appendix B of the DPEIS and in SMCRA regulations at 30 CFR 816.67, note that citizens may file complaints on blasting dust or fumes, subject to investigation by the regulatory authorities, and that the regulatory authorities do have latitude to address respirable dust and fumes.

As proposed in Action 15 of the preferred alternative, Section IV.E.2, the DPEIS proposes to further evaluate current programs for controlling dust and blasting fumes from mountaintop mining and to develop BMPs and/or as appropriate, additional regulatory controls, to further minimize any adverse effects. The PEIS recognizes that the Mine Safety and Health Administration (MSHA) maintains exposure limits for respirable dust. Furthermore, Action 15 of the preferred alternative would evaluate and coordinate current programs for controlling fugitive dust and blasting fumes from MTM/VF operations and develop BMPs and/or additional regulatory controls to minimize adverse effects, as appropriate.

5.2.16 Category: Blasting

This category is a grouping of comments related to blasting vibration, fly rock and property damage. This category corresponds to category 16 in the *Public Comment Compendium* document.

Comments:

SMCRA requires the prevention of damage to property and injury to people but blasting is not being conducted within legal limits and protections are inadequate.

Response:

As discussed in the DPEIS Appendix B, vibration limits are set for ground and air vibrations. The SMCRA rules require the regulatory authority to reduce the limits, if necessary to ensure the prevention of damage or injury. A two-level test is part of each state regulatory program. Vibrations must be within legal limits and off-site damage must be prevented. If vibrations within allowable limits may cause damage (e.g., based on the type of structure or site specific conditions) the blast plan must be changed to lower the limit and ensure damage does not occur.

Comments:

More than 10 complaints exist in Tennessee for the review period of the Blasting-Related Citizen Complaint study of Appendix G.

Response:

Another review of the report reconfirmed that there were only 6 written complaints in the files of OSM's Knoxville Field Office during the review period.

Comments:

Blasting should be classified as a "significant" issue. Reports, anecdotes, site-specific details of blasting complaint information, and newspaper articles are given in support of their position that the regulations should be changed.

Response:

While any property damage or public safety incident is of great concern, studies confirm that existing blasting regulations provide sufficient controls for preventing personal injury and damage to property. The regulatory authorities have the latitude and obligation to take action on a case-by-case basis in the event a blasting-related incident occurs. The DPEIS outlines the rationale for determining the issue not to be significant in Section II.A.3 and further explains the basis for this decision in Section III.W.

5.2.17 Category: Flooding

This category is a grouping of comments related to flooding, contribution of MTM operations to flooding, fear of flooding, and flooding analyses. This category corresponds to category 17 in the *Public Comment Compendium* document.

Comments:

Mountaintop Mining (MTM) operations (along with logging) have caused floods that are more severe now than before MTM mining began. Various explanations were given for why this is happening: The change from pre-mining ground surface conditions, broken rocks during and after, unregulated mining and logging, streams being filled with debris from mines, and poorly designed or failing sediment ponds. Some cited the studies that showed an increase in peak flow from mined areas as proof. While on the other side some cited the same studies showing the streams did not come out of their banks, as mining did not cause flooding. Flooding occurred in areas where there was no mining due to intense rainfall, steep hillsides, small narrow valleys, small road culverts, and trash blocking bridge openings. Some highlighted the conclusions in the referenced studies that found downstream flooding was not significantly increased by existing mining practices if the approved drainage control plans were properly applied.

Response:

The fear of flash flooding has been with most communities that are located in mountainous terrain and justifiably so. The amount of water that flows past any given point is dependant on many factors. These factors include season of the year, weather, antecedent conditions, topography, geology, ground cover, drainage patterns, stream channels configuration, and stream channel obstructions. Mountaintop mining will impact some of these factors within the boundaries of its permit area. However, the hydrologic studies referenced in the PEIS

[Section III.G and Appendix H] do not support the finding that mountaintop mining causes flooding at the mine sites studied. The studies found that these mining operations, using their approved mine plans, would increase peak discharges but would not cause an increase in out of bank flooding. The studies also found that mining-related flooding issues were generally found to be the result of problems associated with implementation and maintenance of the approved mining plan and not the mine plan itself. Each mine is unique and must deal with its own set of influencing factors. A significant effort goes into the design of drainage control plans for mountaintop mining operations. The referenced studies in the PEIS support the success of this design work, but the studies also show the importance of having the drainage control plans implemented and maintained according to plan.

Comments:

The agencies involved should make sure appropriate regulations are in place so flooding would not be allowed.

Response:

The preferred alternative proposes the development of guidelines for calculating peak discharges for design precipitation events and evaluating flood risk. There are regulations already in place that address requirements for controlling flood potential. In Section III.G of the PEIS, there is a discussion of the regulatory requirements that address flooding. Action 16, described in Section II.C.10.b, would further improve the ability to calculate peak discharges and evaluate flooding risk.

Comments:

Streams are being filled with rock and debris from the mountaintop mining sites due to transport of these materials during flooding and this causes the flooding to be worse because the water has nowhere to go.

Response:

Mining operations must be designed under SMCRA to prevent material damage offsite and the CWA Section 402 also precludes offsite sedimentation. Valley fills and backfills on mine sites must also be constructed in a manner that achieves short- and long-term stability. Thus, erosion or sliding of rocks and debris off of a mining permit would be violations of existing provisions. However, the transport and deposition of rocks and debris is a natural process that continually occurs in all stream channels—but can be influenced by other man-made modifications within the watershed, stream channel, or floodplain. The DPEIS studies (see Appendix H and K) found that when significant rainfall events occur, the impacts to the peak runoff vary from site to site. When mountaintop mining operations are conducted in accordance with existing regulatory drainage and sediment controls, they should not cause transport and deposit of rocks and debris offsite.

Comments:

Editorial changes to the executive summary of one of the USGS studies to correct the use of a phrase is suggested.

Specific additional detailed information about the flooding analyses done by the COE be included in the EIS is requested.

Response:

The information on COE flooding analyses is not tracked or relevant to the finalization of the PEIS. As discussed in the DPEIS, Section III.G, many states conduct flooding analyses as part of the SMCRA review. WVDEP's surface water runoff analysis (SWROA) requires that mining not increase the downstream peak above that which would have occurred without mining impacts.

The alternatives contain an action to develop flooding analysis guidelines that should address when flooding analyses are most appropriate. Intuitively, mining sites in closest proximity to residences should receive the most scrutiny; however, all SMCRA permits must include probable hydrologic consequence analyses to demonstrate that the hydrologic balance will not be materially damaged as a result of mining (including flooding assessments).

Comments:

Ponds "break" during rainfall events releasing walls of water. The commenter further indicated concern relevant to the construction of slurry impoundments and underground mines.

Response:

The regulatory authorities (RA) routinely require that ponds be designed to minimize the likelihood of failure. The RA conduct site inspections including observation of the construction, maintenance, and function of the ponds. The regulations also require that a professional engineer certify the proper construction of each pond. These requirements are intended to assure, to the extent possible, that ponds constructed at mine sites are stable and function as intended. As necessary, enforcement actions are taken to further minimize the occurrence of unplanned releases of surface runoff. As discussed in Section III.G.2.d of the PEIS, the Citizen Complaints Study reviewed complaints records for West Virginia, Kentucky, and Virginia. Only a very small percentage of these complaints were concerned with flooding. The study found no documentation of sediment ponds at mountaintop mine sites "breaking" and releasing walls of water into downstream areas. The study did find that enforcement actions were taken as necessary to correct any drainage control structure issues.

In a post-study incident in Lyburn, WV, a large amount of backfill material located above a pond moved rapidly downslope into the pond. This caused a large volume of water to rapidly overtop the pond embankment and did result in what would have essentially been a "wall of water" moving downstream and flooding the downstream area. The pond embankment did not fail (break). The above-referenced Citizen Complaint Study confirmed that this type incident is rare and that the regulatory requirements of the SMCRA program work well to see that ponds are stable and function as designed.

Comments:

Ponds at mountaintop mining sites cause flooding because they are poorly maintained and too small.

Response:

The agencies do not agree with the commenter's assertion. The studies referenced in the PEIS [Section III.G.2.d] did not find that the ponds at mountaintop mining sites were designed and constructed too small to control flooding. The studies did find that in very limited cases, the drainage control structures were not being maintained or constructed in accordance with the approved plan. However, where these situations were identified the RA took enforcement action to require corrections be made to the drainage control structures.

Comments:

There was insufficient information about the SEDCAD 4 analysis in the DPEIS. The commenter requested that the detailed data either be included in the PEIS or the SEDCAD results be removed from the document.

Response:

The plain language summaries of both the HEC-HMS and SEDCAD 4 analysis will be retained as presented in Section III.G.2.a of the PEIS. Both methods were used to do storm runoff modeling. As indicated in the discussion found in the previously referenced section of the PEIS, both models (SEDCAD 4 and HEC-HMS) used identical topographic, land use, and hydrologic conditions or parameters for input in the model analysis. The detailed SEDCAD 4 and HEC-HMS data analysis will not be added to this document. Computer analysis for models such as SEDCAD 4 and HEC-HMS are voluminous, each consisting literally of hundreds of pages of technical data. If the commenter or any other interested party wishes to review the detailed supporting data of the SEDCAD 4 modeling or the HEC-HMS modeling, it can be requested from OSM and the COE respectively. Requests for copies of the SEDCAD 4 or HEC-HMS modeling runs should be submitted in writing to OSM (SEDCAD 4) at 3 Parkway Center, Pittsburgh, PA, 15220 and to the Corps (HEC-HMS) at Pittsburgh District, US Army Corps of Engineers, ATTN: CELRP-EC-WH, 1000 Liberty Avenue, Pittsburgh, PA 15222-4186.

Comments:

The finding of the study titled "Comparison of Storm Response of Streams in Small, Unmined and Valley-Filled Watersheds" in Appendix H of the PEIS is questionable. The commenter is concerned that the location of the data collection sites that were between the valley fills and the sediment pond inappropriately negates the effects of the sediment pond.

Response:

Given the purposes of this study, the agencies do not agree that its findings were questionable. The purposes and limitations of this study are discussed in Appendix H. The study was clear in describing where the data collection sites were located and why they were chosen.

Comments:

The July 2001 Flood Study described in Section III.G.2.c of the PEIS, should not be included in the PEIS because some assumptions made as part of the study are not correct.

Response:

This study, described in Appendix H, was an attempt to fill a data void by collecting information that was not available in previous research or studies. The study articulated the assumptions that it made and the agencies took those assumptions in account in evaluating the flooding issues. The commenter's opinion is noted; however, the study will be included in the PEIS as it should be considered in an evaluation of the flooding issue.

5.2.18 Category: Reclamation

This category is a grouping of comments related to reclamation of mine lands, the positive aspects of reclaimed land, compensatory mitigation, reforestation and reclamation practices that favor introduction of non-native species. This category corresponds to categories 18 and 19 in the *Public Comment Compendium* document.

Comments:

The EIS should consider the positive aspects of reclaimed land such as aesthetics, industrial development, safe housing sites, less severe flooding, and an increase in game.

Response:

The PEIS does consider the positive aspects of reclaimed lands. In Chapters III and IV, the PEIS provided a great deal of information on the issues of post-mining land use, flooding, wildlife and its habitat, and many other issues. The PEIS evaluated the beneficial and adverse effects of mountaintop mining and valley fills and the impacts of the proposed alternatives.

Comments:

Reclamation for surface mine impacts on Appalachian and Cumberland Mountain hardwood forest must include compensatory mitigation and/or reforestation.

Response:

Action 14 (page II.C-83) in the preferred alternative would include Congressional action to require reforestation as a post-mining land use. This action did not indicate whether Congress was likely to take such action.

SMCRA and the CWA do not require that sites forested prior to mining would be re-forested as a part of the post-mining reclamation requirements. The PEIS document identifies and includes analysis of two actions related to this issue. Actions 13 and 14 [Section II.C.8.b] discuss these actions in detail. Section IV.C provides analysis of the anticipated impacts of these two actions.

Comments:

The PEIS should not imply that forestry is the only desirable use of reclaimed mine land.

Response:

The PEIS document does not imply that reforestation of reclaimed mine land is the only desirable post-mining land use. The regulatory limitations related to replanting mined areas under the SMCRA and CWA regulatory requirements are discussed in the above comment response.

Comments:

Approximate original contour (AOC) variance is not applied consistently across states and can be abused.

Response:

The studies prepared for this PEIS do not document any improper implementation of AOC variance provisions. The commenter did not provide any evidence of such improper or abusive implementation. SMCRA does not require that all states implement their regulatory programs in an identical manner. SMCRA allows states to adapt their regulatory programs to the unique circumstances of each state, so long as the programs are no less effective than the provisions of SMCRA and its implementing regulations.

Comments:

The ability to successfully re-establish trees on reclaimed mine sites is questionable. There is little or no evidence to indicate that hardwood forests (1) are or can be successfully established on reclaimed mine sites and (2) that if established, these forests can equal or exceed the forests that existed before mining.

Response:

In Section IV.C.1, the PEIS discusses on-going research related to the establishment of forest communities on reclaimed mine sites. This research, occurring at both Virginia Polytechnic Institute and the University of Kentucky, has demonstrated that forest communities, including a number of different hardwood species, can be successfully re-established on reclaimed mine sites. The above referenced PEIS discussion acknowledges those historic problems that research has identified as having inhibited the successful establishment of forests on reclaimed mine sites and recognizes that there are likely some forest communities such as the cove-hardwood forests that will not be able to be re-established following mining. Although the lead agencies recognize and have acknowledged in the PEIS document that all pre-mining forest communities can not be re-established following mining, given the findings of the on-going research and the recent efforts to emphasize reforestation of mine sites, there can be little doubt that valuable forest communities that meet or exceed pre-mining growth rates can be established on reclaimed mine sites.

Comments:

The DPEIS essentially acknowledges that current reclamation practices, particularly as they relate to soils and vegetation, violate OSM regulations as post-mining soils support lower quality vegetation than did pre-mining soils. In failing to propose any alternative that would include a remedy for these *violations, all the proposed alternatives are illegal and are arbitrary and capricious.*

Response:

The PEIS discusses ongoing efforts to develop new approaches to achieve more effective reforestation under SMCRA (see page IV.C-5). In Section IV.C.1, the PEIS provides a historical perspective on post-SMCRA reclamation with trees, discussing at some length the problems created for the successful establishment of trees in the post-mine environment. The lead agencies included actions in this document that are intended to address the identified reforestation concerns, which involve growth media concerns. Specifically, the PEIS identifies and includes analysis of two actions related to this issue. Actions 13 and 14 [Section II.C.8.b] discuss these actions in detail. Section IV.C provides analysis of the anticipated impacts of these two actions. Existing SMCRA procedures provide remedies for specific alleged violations of reclamation requirements. However, the record of this PEIS does not include documentation of any specific violations of SMCRA regulatory requirements. Therefore, the agencies have found no basis for any additional actions other than those described above and in the PEIS.

Comments:

The use of a BMP manual to merely "encourage" reforestation as a means of mitigating the effects of deforestation is insufficient to meet the requirements of NEPA. NEPA requires that an EIS adequately analyze the effectiveness of proposed mitigation measures. The DPEIS contains no analysis of whether the BMP manual will actually increase reforestation and as such, does not meet NEPA requirements.

Response:

The PEIS document identifies and includes analysis of two actions as part of the preferred alternative related to the issue of reforestation of mountaintop mine sites. Actions 13 and 14 [Section II.C.8.b] discuss these actions in detail. While it is true that proposed Action 13 includes development of BMP guidance related to this issue, proposed Action 14 is predicated on the assumption that regulatory statutes would be changed to require reclamation with trees as the post-mining land use. Section IV.C provides the required NEPA analysis of the anticipated impacts of these two actions.

Comments:

Current reclamation and land use practices create habitat that adversely affects wildlife species and favors introduction of non-native species at the expense of native flora and fauna. The lead agencies should better coordinate and take measures to further reduce the introduction of non-native and invasive species into the reclamation environment.

Response:

As discussed in Section II.A.3.c, the lead agencies commissioned a study that included a review of the use and occurrence of non-native and invasive species on reclaimed mountaintop mining site. Based on a review of the study and the applicable SMCRA regulations, the agencies concluded that this was not a “significant issue” in the context of NEPA and as such, no actions to address this issue were included in the alternatives considered.

Comments:

The commenter supports proposed alternatives that include BMPs related to reclamation and revegetation, particularly revegetation with native species. The commenter is concerned that past revegetation practices that involved certain invasive, non-native species have already resulted in degradation to existing native plant communities and habitats throughout the region.

Response:

The lead agencies considered the many comments that were received that either supported or opposed the different actions and/or alternatives that are presented in this PEIS. The concerns relevant to the impact that invasive, non-native species can have on the environment are duly noted. However, a study commissioned by the lead agencies and discussed in Section II.A.3.c of the PEIS does not support the concern that mine revegetation practices have already degraded existing native plant communities and habitats throughout the region.

Comments:

The PEIS fails to consider the potential problems with large-scale land disturbance and the encroachment of exotic and non-native species. The potential for recolonization of reclaimed mine sites by aggressive nuisance species is extremely high.

Response:

The PEIS did examine the issue of reclamation of mountaintop mine sites and encroachment of exotic and non-native species. As discussed in Section II.A.3.c, the lead agencies commissioned a study that included a review of the use and occurrence of introduced invasive species on reclaimed mountaintop mining site. The study did not support the concern that mine revegetation practices have already degraded existing native plant communities and habitats in the region. Based on a review of the study and the applicable SMCRA regulations, the agencies concluded that this was not a “significant issue” in the context of NEPA and as such, no actions to address this issue were included in the alternatives considered.

6. Errata from the Draft Programmatic Environmental Impact Statement

The following are changes to the DPEIS to make it serve as the FPEIS. All references to paragraphs and sentences are relative to the page indicated. Subheadings are only indicated when the change is on the same page as the subheading. These changes include corrections to minor typographical errors and changes noted in the response to comments. The appendix is a continuation of the errata that includes finalized versions of technical studies that had been in draft form in the DPEIS and studies referenced in agency responses.

- *Executive Summary, page ES-3 third paragraph from the top, second and third sentences, should read:*
  "Conclusions by the authors of the studies were not altered. Their conclusions in the studies do not necessarily reflect the position or view of the agencies preparing this EIS."
- *Executive Summary, page ES-4, fourth bullet from the bottom, last sentence, should read:*
  "Streams with fills generally have lower peak discharges than unmined watersheds during most low-intensity storm events; however, this phenomenon appears to reverse itself during higher-intensity events."
- *Executive Summary, page ES-5 Table ES-1, text in the first row second column should read:*
  "Maintains the regulatory programs, policies, and coordination processes, as well as actions that existed or had been initiated in 2003."
- *Executive Summary, page ES-6 Table ES-1. Text in the second row, second column, sixth line should read*:
  "OSM rules would be finalized to clarify the stream buffer zone rule and make it more consistent with SMCRA. OSM excess spoil rules would be finalized to provide for fill minimization and alternatives analysis, similar to CWA Section 404(b)(1) Guidelines."
- *Executive Summary, page ES-7, ninth bullet should read:*
  Replace the beginning of the sentence with: "Implement existing program requirements, as necessary and appropriate, to ensure that MTM/VF is carried out in full compliance with the Endangered Species Act."
- *Section II.A, page II.A-1, block quote in the second paragraph:*
  "United States" is spelled incorrectly.
- *Section II.A, page II.A-2, subsection 2, last sentence should read:*
  "These cover sheets are an aid to the reader and do not necessarily reflect the conclusions of the agencies."
- *Section II.A, page II.A-5, last line, of the second paragraph:*
  delete the reference, "(see Chapter I.D.2)."
- *Section II.B, page II.B-3, Table II.B-1, text in the first row, second column should read:*
  "Maintains the regulatory programs, policies, and coordination processes, as well as actions that existed or had been initiated in 2003".
- *Section II.B, page II.B-3, Table II.B-1, text in the third row, second column, sixth line should read:*
  "OSM rules would be finalized to clarify the stream buffer zone rule and make it more consistent with SMCRA. OSM excess spoil rules would be finalized to provide for fill minimization and alternatives analysis, similar to CWA Section 404(b)(1) Guidelines."
- *Section II.B.2, page II.B-11, second bullet, should read:*
  "Implement existing program requirements, as necessary and appropriate, to ensure that MTM/VF is carried out in full compliance with the Endangered Species Act."
- *Section II.C.2, page II.C-29 subsection a.2, last sentence should read:*
  "For instance, in West Virginia, the point where the stream segment changes from ephemeral to intermittent is located by a field procedure identifying groundwater levels."

- *Section II.C.10, page II.C-87, third paragraph, next to last sentence, should read:* "The USGS Ballard Fork study found that peak discharge from mined watersheds exceeded peak discharge from unmined watersheds when rainfall intensity was greater than 1 inch per hour."
- *Section II.C.11, page II.C-91, this and all other references to a Biological Assessment or developing a Biological Assessment for the PEIS, should be amended with the following:* "In the process of making a determination of effects pursuant to the Endangered Species Act, the agencies concluded that the preferred alternative would have no effects on T&E species. In coming to this conclusion, the agencies considered the entire record before them, including the fact that in this programmatic EIS, each of the actions in the action alternatives in the PEIS calls for developing certain potential measures to minimize impacts from MTM/VF activities. Each action is conceptual, preliminary, and undeveloped. The agencies have not yet determined the specific techniques or technologies that would be employed, the specific objectives and measures that would apply, or the products, practices, or standards that would result. Because parameters and directions for these actions have not been developed, evaluation of the impacts of the actions on T & E species and their designated critical habitats is not yet feasible. Thus, until development of any action would occur, there would be no effects from the possible action on specific T & E species and their critical habitats."
- *Section II.D.2, page II.D-8, subsection c. last sentence:* "unacceptable" is spelled incorrectly.
- *Section III.C.1, page III.C-10, first paragraph, first sentence should read:* "Fish species present in headwater streams tend to be representative of cold water species or pioneer species adapted to live in ephemeral/intermittent streams, and are primarily sustained by a diet of invertebrates (Vannote *et al*, 1980)."
- *Section III.C.1, page III.C-11, insert additional text after the sentence at the top of the page:* "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 (Stauffer and Ferreri)."
- *Section III.C.1, page III.C-12, second to last bullet under "Biological," should read:* "They enhance fine organic matter transport downstream by breaking down the leaf material"
- *Section III.C.1, page III.C-17, subsection e, third paragraph, third sentence should read:* "This lake is anticipated to be similar to ponds found in the study area."
- *Section III.C.2, page III.C-20, last sentence, should read:* "…may tend to limit the effect of disturbances on the downstream watersheds although the streams and ponds do not replace the structure and function of original first and second order watersheds (Wallace, B. in EPA et al. March 20, 2000)"
- *Section III.D.1, page III.D-3, subsection b.2:*

all references to the USGS 2002 Draft “E-point, P-point” study should instead refer to the USGS 2003 ephemeral points and perennial points study.

- *Section III.D.1, page III.D-5, subsection e, first paragraph, second sentence should read:* “One study of the impact of valley fills on stream flows was performed by the USGS (USGS 2001c) on one stream below a valley fill site (at the toe of the valley fill) and one stream below an unmined site, and comparing one flow parameter at many streams with and without filling in the watershed.”
- *Section III.D.1, page III.D-7, subsection f.2, first paragraph, second sentence should read:*
  “These changes include increases in a number of constituents and properties that are known to be associated with surface mining…”
- *Section III.D.1, page III.D-9, subsection h.1, second paragraph, last sentence should read:*
  “In addition, other metrics that evaluate the diversity, evenness and degree of pollution tolerance…”
- *Section III.D.1, page III.D-15, subsection i, second paragraph, first sentence should read:*
  “A study of fish communities and the responses to environmental factors…”
- *Section III.D.1.i, page III.D-17, add to the top of paragraph:*
  “In 2003 the FWS collected fish in streams downstream of valley fills, where earlier water quality analysis [Appendix D] had revealed high selenium concentrations. The results demonstrated that the selenium is biologically available for uptake into the food chain, and that violations of the EPA selenium water quality criteria may result in selenium concentrations in fish that could adversely affect fish reproduction. In some cases, fish tissue concentrations were near levels believed to pose a risk to fish-eating birds. It is likely that benthic invertebrates in some of these streams would be similarly contaminated, thereby posing a risk to birds such as Louisiana waterthrush that depend upon aquatic insects as a food supply.” (January 16, 2004, letter from David Densmore, FWS, to Allyn Turner, WVDEP).
- *Section III.D.2, page III.D-19, second paragraph, last sentence should be replaced with:* “Wallace (EPA 2000) suggested that these types of systems can be important sites of nutrient storage and uptake provided that a sufficiently vegetated littoral zone is present, and the reconstructed wetland is linked to the downstream watershed. Dr. Wallace stated that while these wetlands have value, he does not believe that these constructed wetlands replace the pre-mining streams. However, he noted, the wetlands do tend to limit the effect of disturbances on the downstream watersheds.”
- *Section III.D, page III.D-21, first paragraph, lines 7-9 delete the statement:*
  “However, it is not known whether the organic matter processing that occurs in created wetlands would mimic the processing found in a natural stream system” should be deleted.
- *Section III.E.2, page III.E-3, second paragraph, second sentence should read:*
  “Aluminum solubility is very low, less than 0.5 mg/L, at pH of approximately 7.”

- *Section III.E.2, page III.E-5, second paragraph, second sentence should read:*
  "In most natural or unpolluted surface waters, soluble iron is either near or less than quantifiable concentrations due to its relative insoluble properties in oxidizing and water environments at pH of approximately 7."
- *Section III.E.2, page III.E-5, third paragraph, third sentence should read:*
  "In most natural or unpolluted surface waters, soluble manganese is absent due to its limited solubility in oxidizing and water environments at pH of approximately 7 similar to iron."
- *Section III.E.2, page III.E-5, fourth paragraph, second sentence should read:*
  "The presence or absence of aluminum is a direct result of pH-dependent solubility, with aluminum solubility increasing from, much less than 1 mg/L at pH of approximately 7, to greater than 100 mg/l at pH less than 3 (Stumm and Morgan 1996)."
- *Section III.E.3, page III E-6, subsection b, third paragraph, insert before the last sentence:*
  "Flocculants and precipitates associated with mine drainage can cement substrates and contribute to streambed armoring."
- *Section III.F.1, page III.F-3, second full paragraph, last sentence:*
  change the word, "tress," to "trees."
- *Section III.F.3, page III.F-7, subsection a, second paragraph, second sentence should read:*
  "This change in available habitat has resulted in an increase in the abundance of edge and grassland bird species at reclaimed mountaintop mining sites (Wood and Edwards, 2001; Canterbury, 2001)."
- *Section III.F.3, page III.F-9, subsection c, third paragraph, beginning of the first sentence should read:*
  "Herptofaunal species richness and abundance…"
- *Section III.G.2, page III.G-4 Insert at the end of the last paragraph:*
  "Requests for copies of the SEDCAD 4 or HEC-HMS modeling runs should be submitted in writing to OSM (SEDCAD 4) at 3 Parkway Center, Pittsburgh, PA, 15220 and to the Corps (HEC-HMS) at Pittsburgh District, US Army Corps of Engineers, ATTN: CELRP-EC-WH, 1000 Liberty Avenue, Pittsburgh, PA 15222-4186."
- *Section III.G.2, page III.G-7, subsection b., first sentence of the last paragraph, should read:*
  "During most of the recorded storms (low intensity), the peak flows (per unit area) for the unmined watershed and the cumulative watershed were greater than the mined watershed."
- *Section III.K.4, page III.K-38, subsection a, first sentence:*
  change the word "competed" to "completed."
- *Section III.L.3:*
  pages III.L-14 - III.L-17 are missing. They are reproduced in the appendix.
- *Section IV.D, page IV.D-4, first paragraph, second sentence, add following reference:*
  (67 FR65083 (Oct 23, 2002))

- *Section IV.D, page IV.D-5, subsection 1.e, first paragraph, last sentence should read:*
  "The Federally-listed species and habitat information are summarized in Appendix F of this EIS."
- *Section V, page V-41, insert the following two references before the third reference from the bottom:*
  "West Virginia Legislative Auditor, Performance Evaluation And Research Division. *Preliminary Performance Review. The Office of Explosives and Blasting.* PE 02-36-268. December 2002."

  "West Virginia Legislative Auditor, Performance Evaluation And Research Division. *Preliminary Performance Review. The Office of Explosives and Blasting.* PE 03-23-298. November 2003."
- *Appendix D:*
  The Fulk 2003 study should be replaced with the final 2003 version with pagination. This study is provided in the errata continuation appendix.
- *Appendix E:*
  The Handel study on the CD version of the EIS and on the website should be replaced with the March 2003 version. This study is provided in the errata continuation appendix.
- *Appendix H:*
  The July 2001 USGS flooding study should be part of appendix H. This study is provided in the errata continuation appendix.

The following items are in the errata continuation appendix:

- Pages III.L-14 - III.L-17 from the DPEIS
- USFWS letter report
- USGS Water Quality in the Kanawha-New River Basin
- Handel 2003 study text final version
- Fulk 2003 study, final version with pagination
- "Amphibian utilization of sediment control structures compared to a natural vernal pool located on mine permitted areas in southern West Virginia." Conducted for Pen Coal by R.E.I. Consultants, report dated 22 April 2000.
- "A History of the Benthic Macroinvertebrate and Water Chemistry Studies of two Long-term Monitoring Stations on Trough Fork" Conducted for Pen Coal by R.E.I. Consultants, report dated 20 June 2000.
- Weakland, Cathy, A., and Wood, Petra Bohall. "Cerulean Warbler (Dendroica Cerulea) Microhabitat and Landscape-level Habitat Characteristics in Southern West Virginia in Relation to Mountaintop Mining/Valley Fills". Final Project Report. USGS Biological Resources Division and West Virginia University, Division of Forestry. December 2002.
- Selenium Workshop, April 13th, 2004 Charleston, WV. Summary
- USGS 2001 Flooding Study

7. List Of Preparers

This document was prepared by the U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Office of Surface Mining, U.S. Fish and Wildlife Service, and West Virginia Department of Environmental Protection, with assistance from Gannett Fleming, Inc. The individuals listed below had principal roles in the preparation and content of this document. Many others had significant roles and contributions as well and their efforts were no less important to the development of this FPEIS. These others include senior managers, administrative support personnel, legal staff, and technical staff.

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Federal Emergency Management Agency
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- Natural Resources Conservation Service

U.S. Department of Commerce
- U.S. Department of Defense
- U.S. Army Corps of Engineers
  - HQ, Washington, DC
  - Huntington District
  - Louisville District
  - Nashville District
  - Norfolk District
  - Pittsburgh District

U.S. Department of Energy
U.S. Department of Homeland Security
U.S. Department of the Interior
- U.S. Fish & Wildlife Service
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  - SW Virginia Field Office, Abingdon, VA
  - VA Field Office, Gloucester, MA
  - TN Field Office, Cookeville, TN
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  - WV Field Office, Elkins, WV
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- U.S. Geological Survey
  - Water Resources Division, WV District Office
- U.S. Office of Surface Mining
  - Appalachian Regional Coordinating Center, Pittsburgh, PA
  - KY — Lexington; London; Madisonville; Pikeville
  - TN — Knoxville
  - VA — Big Stone Gap
  - WV — Beckley; Charleston; Morgantown
- Office of Environmental Policy and Compliance
- National Park Service

U.S. Department of Justice
U.S. Department of Labor

U.S. Department of State
U.S. Department of Transportation
 Federal Highway Administration
 U.S. Environmental Protection Agency
 Headquarters, Washington, DC
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Other Agencies

Advisory Council on Historic Preservation
Interstate Commerce Commission

State Agencies

Kentucky
- Department of Surface Mining Reclamation and Enforcement
  - Office of the Commissioner
  - Pikeville; London; Middlesboro; Prestonsburg

Ohio
- Ohio Environmental Protection Agency

Tennessee
- Department of Environment and Conservation

Virginia
- Department of Mines, Minerals & Energy
  - Mined Land Reclamation
    - Keen Mountain; Big Stone Gap

West Virginia
- Department of Environmental Protection
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- Division of Natural Resources
  - Charleston; Elkins

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10. Reader's Guide to Acronyms

ADID	Advanced Identification
APA	Administrative Procedures Act
AOC	Approximate Original Contour
BMP	Best Management Practices
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CHIA	Cumulative Hydrologic Impact Assessment
CMD	Coal Mine Drainage
COE	U.S. Army Corps of Engineers
CWA	Clean Water Act
DPEIS	Draft Programmatic Environmental Impact Statement. This acronym is used when describing or referring to the DPEIS released June 2003.
EIS	Environmental Impact Statement
FPEIS	Final Programmatic Environmental Impact Statement. This acronym is used when describing or referring to the FPEIS that incorporates the draft document released June 2003.
EO	Executive Order
ESA	Endangered Species Act of 1973
EPA	United States Environmental Protection Agency
e.g.	For example
FR	Federal Register
FWS	United States Fish and Wildlife Service (U.S. Department of the Interior)
IP	Individual Permit
JPP	Joint Permit Processing
MOU	Memorandum of Understanding
MTM	Mountaintop Mining
MTM/VF	Mountaintop Mining/Valley Fill
NEPA	National Environmental Policy Act of 1969, P.L. 91-190
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NWP	Nationwide Permit
OSM	United States Office of Surface Mining (U.S. Department of the Interior)
PEIS	Programmatic Environmental Impact Statement

PHC	Probable Hydrologic Consequences
PIR	Public Interest Review
P.L.	Public Law (of the United States)
ppb	parts per billion
SBZ	Stream Buffer Zone
SMCRA	Surface Mining Control and Reclamation Act of 1977
TMDL	Total Maximum Daily Loads
USGS	United States Geological Survey (U.S. Department of the Interior)
U.S.	United States
WVDEP	West Virginia Department of Environmental Protection

Appendix
Errata Continuation

Pages Missing from DPEIS

Table III.L-5
Example MTM/VF Mine Economic Analysis
MANPOWER TABLE

Period: Full Year

Production Days = 260 days

C.T. Per M.H.		7.25
BCY Per M.H.		108.90

Manpower				Job Description	O.B. Production	# Prod. Days	Hrs. Per Day	Total Manhours
Position	Day	Evening	Total					
25 yd. Front Shovel	1	1	2	O.B. Loading	7,500,000	260	10	5,200
210 Ton Rock Truck	3	3	6	O.B. Haulage		260	10	15,600
Fill Dozer	1	1	2	Run Fill		260	10	5,200
18 ½ yd. Backhoe	1	1	2	O.B. Loading	5,800,000	260	10	5,200
150 Ton Rock Truck	3	3	6	O.B. Haulage		260	10	15,600
Fill Dozer	1	1	2	Run Fill		260	10	5,200
16 yd. Endloader	1	1	2	O.B. Loading	4,100.,000	260	10	5,200
150 Ton Rock Truck	2	2	4	O.B. Haulage		260	10	10,400
Fill Dozer	1	1	2	Run Fill		260	10	5,200
45 yd. Bull Dozer	4	4	8	Prod. Dozing	7,800,000	260	10	20,800
Development Dozer	2	2	4	Development		260	10	10,400
Reclamation Dozer	1	1	2	Reclamation		260	10	5,200
16 yd. Coal Loader	2	2	4	Coal Prep. Ldg.		260	10	10,400
9 yd. Coal Loader	2	2	4	Coal Prep. & Ldg.		260	10	10,400
Drillers	4	3	7	O.B. Drilling		260	10	18,200
Motor Grader	1	1	2	Road Maint.		260	10	5,200
Water Truck	1	1	2	Dust Control		260	10	5,200
Mechanics/Welders	2	6	8	Maintenance		260	10	20,800
P.M. Technicians	1	2	3	Maintenance		260	10	7,800
Fueler/Greaser	1	1	2	Maintenance		260	10	5,200
Blasters	6	0	6	Blasting		260	10	15,600
Blasting foreman	1	0	1	D & B Superv.		260	10	2,600
Prod. Foreman	1	1	2	Shift Superv.		260	10	5,200
Maint. Foreman	1	1	2	Maint. Superv.		260	10	5,200
Maint. Planner	1	1	2	Maint. Scheduling		260	10	5,200
Prod. Engineer	1	0	1	Engineering		260	10	2,600
Superintendant	1	0	1	General Superv.		260	10	2,600
Total	47	42	89		25,200,000			231,400

Source: Meikle & Fincham, 1999

Table III.L-6
Example MTM/VF Mine Economic Analysis of Earnings Before Interest and Taxes

	Total Project		
Parameter	**$$**	**$$ Per BCY**	**$$ Per C.T.**
Revenues	$405,800,604	$1.65	$24.75
Revenues Per ton	$24.75		
Non-Mining Costs:			
Sales Related Costs	$59,771,560	$0.24	$3.65
Intercompany Royalties	$0	$0.00	$0.00
Intercompany Commissions	$4,098,996	$0.02	$0.25
Trucking	$33,666,422	$0.14	$2.05
Other Transportation Costs	$9,837,593	$0.04	$0.60
Preparation Costs	$12,752,441	$0.05	$0.78
Subtotal	$120,127,012	$0.49	$7.33
Net Realization	$285,673,592	$1.16	$17.42
Indirect Costs:			
Overhead	$8,996,465	$0.04	$0.55
Reclamation	$2,459,394	$0.01	$0.15
Subtotal	$11,455,859	$0.05	$0.70
Mining Costs:			
Labor	$83,956,796	$0.34	$5.12
Supplies	$112,056,241	$0.45	$6.83
Subtotal	$196,013,037	$0.80	$11.95
Cash Margin	$78,204,696	$0.32	$4.77
Cash Margin Per Ton	$4.77		
Cash Cost Per Ton	$19.98		
Direct D.D. & A.	$51,691,246	$0.21	$3.15
Indirect D.D. & A.	$0	$0.00	$0.00
Subtotal	$51,691,246	$0.21	$3.15
Earnings Before Interest & Taxes	$26,513,450	$0.11	$1.62

Source: Meikle & Fincham, 1999

Table III.L-7
Example MTM/VF Mine Economic Analysis
CAPITAL INVESTMENT STATISTICS ($millions)

Parameter	Initial Inv. Year 0	Year #1	Year #2	Year #3	Year #4	Year #5	Year #6	Year #7	Year #8	Year #9	Year #10	Year #11
E.B.I.T.	$0.00	$2.43	$2.57	$2.64	$2.79	$2.82	$1.45	$1.55	$1.70	$5.22	$3.33	$0.00
Taxes @ 30%	$0.00	$0.73	$0.77	$0.79	$0.84	$0.85	$0.44	$0.47	$0.51	$1.57	$1.00	$0.00
Commissions	$0.00	$0.42	$0.42	$0.42	$0.42	$0.42	$0.42	$0.42	$0.42	$0.42	$0.32	$0.00
Taxes on Comm.	$0.00	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.10	$0.00
Intercompany Royalty	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Taxes on Intercompany	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Tax Savings Depl.	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Net Income	$0.00	$2.09	$2.14	$2.14	$2.25	$2.27	$1.31	$1.38	$1.49	$3.95	$2.56	$0.00
(Add) DD&P	$0.00	$5.29	$5.29	$5.29	$5.22	$5.23	$6.53	$6.53	$6.48	$2.97	$2.85	$0.00
(Less) CapEx	$3.86	$37.06	$0.48	$0.23	$0.48	$2.78	$10.66	$1.70	$0.00	$2.55	$0.00	($6.65)
Net Cash Flow	($3.86)	($29.77)	$6.90	$7.21	$6.99	$4.72	($2.82)	$6.21	$7.97	$4.37	$5.41	$6.65

N.P.V. @ 5%	$7.45
N.P.V. @ 8%	$2.26
N.P.V. @ 10%	($0.52)
I.R.R.	9.60%
Payback Period	7.56 yrs

Cash Flows 1 - 11	
E.B.I.T.	$26.51
Net Inc.	$21.43
Net Cash	$19.98

Source: Meikle & Fincham, 1999

Table III.L-8
Individual Taxes
By Total Mine Life Cost and Cost Per Ton of Coal

Taxes	Total Mine Life Cost	Cost Per Ton of Coal
Personal Property Tax	$3,132,574	$0.19 per ton
Worker's Compensation	$5,559,085	$0.34 per ton
Matching FICA	$3,097,378	$0.19 per ton
Unmined Mineral Tax	$1,173,000	$0.07 per ton
Franchise Tax	$504,390	$0.03 per ton
Severance Tax	$20,290,033	$1.24 per ton
Black Lung Tax	$8,747,264	$0.53 per ton
Federal Reclamation Tax	$5,566,431	$0.34 per ton
WV Special Assessment	$819,798	$0.05 per ton
Federal & State Income Tax	$9,183,734	$0.56 per ton
TOTAL	**$58,073,684**	**$3.54 per ton**

Individual taxes and tax rates vary between states in the study area. It is predicted that total taxes would be $4,189,994 less if this same operation where conducted in Kentucky, and $12,187,134 less if it were conducted in Virginia.

4. Mining Method Considerations

Selection of the appropriate mining method(s) for a given site is a complicated, iterative process during the mine feasibility evaluation and planning stages. Choices are typically driven by the desire to maximize coal recovery with the least expensive mining method that is practical for a given coal seam. This section summarizes the basic considerations for mine method selection.

a. Mine Method Selection Factors

The two basic options in mine method selection are surface and underground mining, or a combination of the two. For surface operations, contour, area, and mountaintop removal methods are available individually or in combination, and room and pillar and/or longwall mining are available for underground operations. The primary factors used for deciding between the individual methods are summarized in Table III.L-9.

USFWS letter report

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Pennsylvania Field Office
Suite 322
315 South Allen Street
State College, Pennsylvania 16801

January 16, 2004

Allyn Turner
Director, Division of Water and Waste Management
West Virginia Department of Environmental Protection
414 Summers Street
Charleston, WV 25301

Dear Ms. Turner:

During the spring and summer of 2003, we conducted a survey of selenium in fish, water, and sediments in various waterbodies in southern West Virginia. Because U.S. Environmental Protection Agency studies for the draft Environmental Impact Statement on Mountaintop Mining/Valley Fills found high selenium concentrations in waters downstream of valley fills, and selenium is highly bioaccumulative and toxic to fish and wildlife, we were interested in determining whether the waterborne selenium downstream of valley fills is accumulating in fish tissues to ecologically relevant levels. In addition, because mercury is associated with coal and also bioaccumulates, we initially included mercury in our chemical analysis.

We conducted our sampling May 28-30, and August 19-21, 2003. Most of the streams we sampled were previously sampled for selenium in water by EPA or WVDEP. As a cost-saving measure, we did not collect water samples in those locations; however, we did collect a sediment sample at each location. When sampling stream fish, we targeted primarily creek chubs and blacknose dace. These species are efficient bioaccumulators of selenium (bioaccumulation factors of 4,545 and 4,590, respectively; Mason *et al.* 2000), and would be expected to serve as a food source for birds such as the belted kingfisher and great blue heron. Selenium in fish consumed by these birds could be transferred to offspring in bird eggs, resulting in embryo mortality or deformity (Lemly 2002).

We also sampled East Lynn and Beech Fork Lakes in Wayne County, and one stream in each of their watersheds (Trough Fork and Miller's Fork, respectively). The East Lynn watershed is heavily mined, while the Beech Fork watershed is relatively undisturbed by mining. For the lakes, we targeted bluegill, largemouth bass, gizzard shad, and white crappie. Samples included whole fish, fillet (left side, skin on, scaled), and eggs.

Table 1 provides results for streams in the Little Coal/Coal River, Big Coal River, and Mud River watersheds, and one sedimentation pond downstream of a valley fill at the head of Trace

Branch. Table 2 provides results for East Lynn and Beech Fork Lakes, and Trough and Miller's Forks.

Mercury analysis was conducted only on samples collected in May. Mercury was found in only one stream fish sample (creek chubs from Stanley Fork), but was present in many of the lake fish samples. Mercury was not found in any of our sediment samples, or in any of four water samples. Because of the low incidence of detections in the stream samples, we did not submit the August stream samples for mercury analysis.

Selenium was present in all fish samples. As a guideline for evaluating the ecological significance of the selenium concentrations, we used Lemly (2002). Based on a synthesis and interpretation of scientific literature, Lemly has established "toxic effect thresholds for selenium in aquatic ecosystems," which he describes as "levels at which toxic effects begin to occur in sensitive species of fish and aquatic birds. They are not levels that signify the point at which all species die from selenium poisoning" (p. 31). Lemly's values and associated biological effects in fish are 8 ppm (dw) for fillets[1] (reproductive failure); 10 ppm for eggs (reproductive failure); and 4 ppm for whole fish (mortality of juveniles and reproductive failure). For reproductive failure in birds, Lemly cites 7 ppm in food chain organisms.

Creek chubs and blacknose dace collected from Trace Branch, Sugartree Branch, and Stanley Fork (where EPA or WVDEP had previously identified selenium water concentrations above the EPA chronic water quality criterion of 5 µg/l) contained selenium at concentrations above Lemly's 4 ppm toxic effect threshold level for whole fish. Our water sample from a valley fill sedimentation pond at the head of Trace Branch hollow contained 6.44 µg/l selenium, and bluegill captured in the pond contained 6.89 ppm selenium. Selenium levels in fish samples from the Trace Branch pond and Sugartree Branch were just below the 7 ppm threshold value for reproductive failure in birds.

Fish from several streams where other agencies had documented stream selenium concentrations greater than the EPA criterion did not exceed the Lemly threshold values. Among many possible explanations for this is evidence that other water quality parameters, especially sulfates, can interfere with selenium uptake (Great Lakes Environmental Center 2002). In studies related to the EIS for mountaintop mining, EPA identified high sulfate concentrations at many sampling locations.

No fish or fish eggs collected from Beech Fork Lake or East Lynn Lake contained selenium at concentrations above Lemly's thresholds. However, tissue selenium concentrations were generally higher in the East Lynn samples, and long-term monitoring of this situation is advisable. Selenium concentrations in creek chub samples from both Trough Fork and Miller's Fork were low relative to other streams in our survey.

Our results show that selenium present in surface waters in southern West Virginia is bioavailable, and that violations of the EPA selenium water quality criterion may result in

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[1]Note that Lemly's fillet values are for skinless fillets, and our samples were skin-on.

selenium concentrations in fish that could adversely affect fish reproduction. In some cases, fish tissue concentrations were near levels believed to pose a risk to fish-eating birds. It is likely that benthic invertebrates in some of these streams would be similarly contaminated, thereby posing a risk to birds that depend upon aquatic insects as a food supply (*e.g.*, Louisiana waterthrush). Accordingly, we believe that the potential for release of selenium during and after mining should be assessed to ensure that future permits are not issued where there is a likelihood that selenium water quality standards will be violated. We are aware that the West Virginia Geological Survey has analyzed the selenium content of coal in various locations (www.wvgs.wvnet.edu/www/datastat/te/Maps/Semapmax.gif). If those results can be correlated to the selenium water and fish data, it may be possible to develop coal and/or overburden analysis requirements for permit applicants that would characterize the degree of selenium risk associated with a given application.

If you have any questions regarding this information, please contact Cindy Tibbott of my staff at 814-234-4090, ext. 226.

Sincerely,

David Densmore
Supervisor

Literature Cited

Great Lakes Environmental Center. 2002. Draft aquatic life water quality criteria for selenium. Traverse City, MI.

Lemly, A.D. 2002. Selenium assessment in aquatic ecosystems: Aguide for hazard evaluation and water quality criteria. New York: Springer-Verlag New York, Inc. 162 pp.

Mason, R. P., J-M. Laporte, and S. Andres. 2000. Factors controlling the bioaccumulation of mercury, arsenic, selenium, and cadmium by freshwater invertebrates and fish. Arch. Environ. Contam. Toxicol. 38:283-297 (as cited in Great Lakes Environmental Center 2002).

Table 1. Results of sediment, water, and fish tissue analyses for selenium and mercury in samples collected from various waterbodies in southern West Virginia.

Location, collection date, lat/long	Other agency station code	Other agency Se water (mean, ug/l)	Sediment Se (ppm)	Water Se and Hg (ug/l)	Fish species (whole fish)	Mean fish size (mm)	Fish Se (ppm, dw)	Fish Hg[1] (ppm,dw)
Little Coal/Coal River Watersheds								
Spruce/White Oak Branch 28-May-03 37.86289, -81.803831	EPA MT 39	ND (<2.99)	ND (<0.229)		Creek chub Creek chub Creek chub	101 146 72	1.86 1.43 3.19	ND ND ND
Coal/Trace Branch Pond 29-May-03 37.87704, -81.84137			0.525	Hg-ND (<0.100) Se- 6.44	Bluegill	152	6.89	ND
Coal/Left Fork Beech 28-May-03 37.905423, -81.846021	EPA MT 34B	22.7	0.486		Creek chub	142	3.05	ND
Coal/Trace Branch 29-May-03 37.87655, -81.83786	WVDEP WVKC-10-T-19	6.4	ND (<0.240)		Creek chub Creek chub	159 100	5.5 6.04	ND ND
Big Coal River Watershed								
Ewing Fork 20-Aug-03 37.91067, -81.32799	EPA MT 69	ND (<2.99)	0.221	Hg 1.5 Se ND (<2.5)	Blacknose dace	77	2.9	
Clear Fork/Sycamore Creek 20-Aug-03 37.93762, -81.42299	EPA MT 81	ND (<2.99)	0.113	Hg 1.01 Se ND (<2.5)	Blacknose dace Creek chub	71 109	2.45 0.845	
Clear Fork/Rockhouse Creek 19-Aug-03 37^0 57.952, -81^0 30.096	WVDEP WVKC-47A	<5	0.455		Blacknose dace Creek chub	77 92	1.86 1.33	
White Oak/ Left Fork 19-Aug-03 38 03 0.7, 81 31 41	WVDEP WVKC-35E	7	1.49		Creek chub	98	1.73	
Seng Creek 20-Aug-03 37^0 59.981, 81^0 29.274	WVDEP WVKC-42	16	0.479		Blacknose dace Creek chub	84 135	2.75 2.06	
Buffalo Fork 20-Aug-03 37.899, -81.331	EPA MT 64	13	0.387		Blacknose dace	72	0.91	

Table 1 (continued).

Location, collection date, lat/long	Other agency station code	Other agency Se water (mean, ug/l)	Sediment Se (ppm)	Water Se and Hg (ug/l)	Fish species (whole fish)	Mean fish size (mm)	Fish Se (ppm, dw)	Fish Hg[1] (ppm,dw)
Mud River Watershed								
Mud/Rushpatch Branch 21-Aug-03 38.04966, -81.93302	EPA MT 02	ND (<2.99)	ND (<0.0679)	Hg 0.952 Se ND (<2.5)	Blacknose dace	59	0.907	
					Creek chub	109	<0.481	
Mud/Stanley Fork 30-May-03 38.08506, -81.95601	EPA MT 15	12.1	ND (<0.245)		Creek chub	185	4.13	0.28
					Creek chub	84	5.11	ND
Mud River 21-Aug-03 38.09191, -81.97446	EPA MT 23	12.9	0.134		Creek chub	108	1.4	
Mud/Sugartree Branch 30-May-03 38.09084, -81.95262	EPA MT 18	36.8	0.192		Blacknose Dace	75	6.52	ND
					Creek chub	104	6.85	ND

[1] Mercury detection limits for fish tissue samples ranged from 0.145 to 0.200 ppm. August 2003 fish samples were not submitted for mercury analysis.

Table 2. Results of sediment, water, and fish tissue analyses for selenium and mercury in samples collected from East Lynn and Beech Fork Lakes, and Trough and Miller's Forks, Wayne County.

Location, collection date, lat/long	**Sediment [1] Se (ppm dw)**	**Water Se and Hg (µg/l)**	**Fish species & tissue**	**Mean fish size (mm)**	**Tissue Se (ppm, dw)**	**Tissue Hg[2] (ppm, dw)**
East Lynn Lake June 2, 2003 38.04561, -82.25049	ND <0.238	ND <.0999 Hg < 2.5 Se	Bluegill - 5 whole fish	89 - 113	1.60	ND
			Gizzard shad - 5 whole fish	89 - 100	3.29	ND
			Largemouth bass - 1 whole fish (female, eggs removed)	260	1.72	0.340
			Largemouth bass - 2 whole fish	272	3.84	0.370
			White crappie - 2 whole fish	201	0.863	0.175
			Largemouth bass - fillets from 5 fish	337	3.25 dw, 0.772 ww	1.00 dw, 0.238 ww
			Gizzard shad - eggs from 1 fish	285	3.54	ND
			Largemouth bass - eggs from 1 fish (remainder analyzed whole – see above)	260	3.17	ND
			Largemouth bass - eggs from 3 fish	343	4.73	ND

Location, collection date, lat/long	Sediment [1] Se (ppm dw)	Water Se and Hg (µg/l)	Fish species & tissue	Mean fish size (mm)	Tissue Se (ppm, dw)	Tissue Hg[2] (ppm, dw)
Beech Fork Lake June 3, 2003 38.3133, -82.36219	ND (<0.238)	ND (Hg <0.100 Se <2.50)	Bluegill - 5 whole fish	100	0.600	ND
			Bluegill - 3 gravid females	149	0.635	ND
			Largemouth bass - 3 whole fish	328.	0.871	0.613
			White crappie - 5 fish	125	0.600	0.360
			Largemouth bass - fillets from 1 gravid female	455	1.76 dw, 0.422 ww	2.16 dw, 0.517 ww
			Largemouth bass - fillets from 1 gravid female and 1 male	400 (f) 370 (m)	1.26 dw, 0.490 ww	0.368 dw, 0.143 ww
			Bluegill - eggs from 3 fish	153	1.08	ND
			Largemouth bass - eggs from 1 fish (same fish used for fillet, above)	455	2.06	ND
			Largemouth bass - eggs from 1 fish	400	2.48	ND
Trough Fork June 4, 2003 38.04561, -82.25049	ND (<0.248)		Creek chub	7.5-10 (5 fish)	0.564	ND
Miller's Fork June 4, 2003 38.04561, -82.25049	ND (<0.243)		Creek chub	7.5-8.5 (5 fish)	0.713	ND

[1] Mercury was not detected in sediments. The detection limits ranged from 0.917 to 0.0990 ppm.

[2] Mercury detection limits for tissue samples ranged from 0.145 to 0.200 ppm.

USGS Water Quality in the Kanawha-New River Basin

science for a changing world

Water Quality in the Kanawha–New River Basin

West Virginia, Virginia, and North Carolina, 1996–98

U.S. Department of the Interior
U.S. Geological Survey

Circular 1204

POINTS OF CONTACT AND ADDITIONAL INFORMATION

The companion Web site for NAWQA summary reports:

http://water.usgs.gov/nawqa/

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Reston, VA 20192
http://water.usgs.gov/nawqa/

Other NAWQA summary reports

River Basin Assessments

Albemarle-Pamlico Drainage Basin (Circular 1157)
Allegheny and Monongahela River Basins (Circular 1202)
Apalachicola-Chattahoochee-Flint River Basin (Circular 1164)
Central Arizona Basins (Circular 1213)
Central Columbia Plateau (Circular 1144)
Central Nebraska Basins (Circular 1163)
Connecticut, Housatonic, and Thames River Basins (Circular 1155)
Eastern Iowa Basins (Circular 1210)
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Las Vegas Valley Area and the Carson and Truckee River Basins (Circular 1170)
Lower Illinois River Basin (Circular 1209)
Long Island–New Jersey Coastal Drainages (Circular 1201)
Lower Susquehanna River Basin (Circular 1168)
Mississippi Embayment (Circular 1208)
Ozark Plateaus (Circular 1158)
Potomac River Basin (Circular 1166)
Puget Sound Basin (Circular 1216)
Red River of the North Basin (Circular 1169)
Rio Grande Valley (Circular 1162)
Sacramento River Basin (Circular 1215)
San Joaquin–Tulare Basins (Circular 1159)
Santee River Basin and Coastal Drainages (Circular 1206)
South-Central Texas (Circular 1212)
South Platte River Basin (Circular 1167)
Southern Florida (Circular 1207)
Trinity River Basin (Circular 1171)
Upper Colorado River Basin (Circular 1214)
Upper Mississippi River Basin (Circular 1211)
Upper Snake River Basin (Circular 1160)
Upper Tennessee River Basin (Circular 1205)
Western Lake Michigan Drainages (Circular 1156)
White River Basin (Circular 1150)
Willamette Basin (Circular 1161)

National Assessments

The Quality of Our Nation's Waters—Nutrients and Pesticides (Circular 1225)

Front cover: The Kanawha River at Kanawha Falls, West Virginia. *(Photograph by David Fattaleh, West Virginia Division of Tourism, and used by permission.)*

Back cover: Left, Electrofishing on Sewell Creek at East Rainelle, West Virginia *(photograph by Edward Vincent, USGS)*; right, Mountaintop coal mine near Kayford, West Virginia *(photograph by James H. Eychaner, USGS)*.

Water Quality in the Kanawha–New River Basin

West Virginia, Virginia, and North Carolina, 1996–98

By Katherine S. Paybins, Terence Messinger, James H. Eychaner, Douglas B. Chambers, *and* Mark D. Kozar

U.S. GEOLOGICAL SURVEY CIRCULAR 1204

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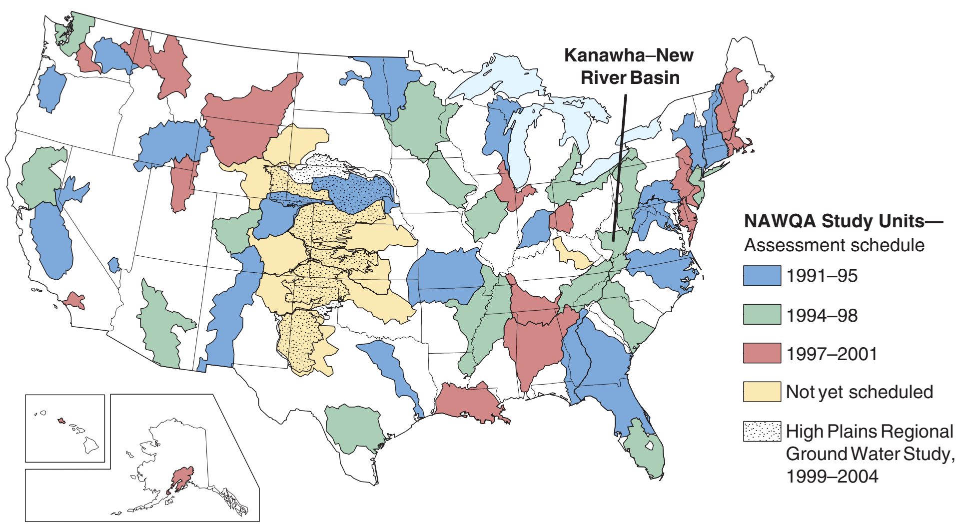
CONTENTS

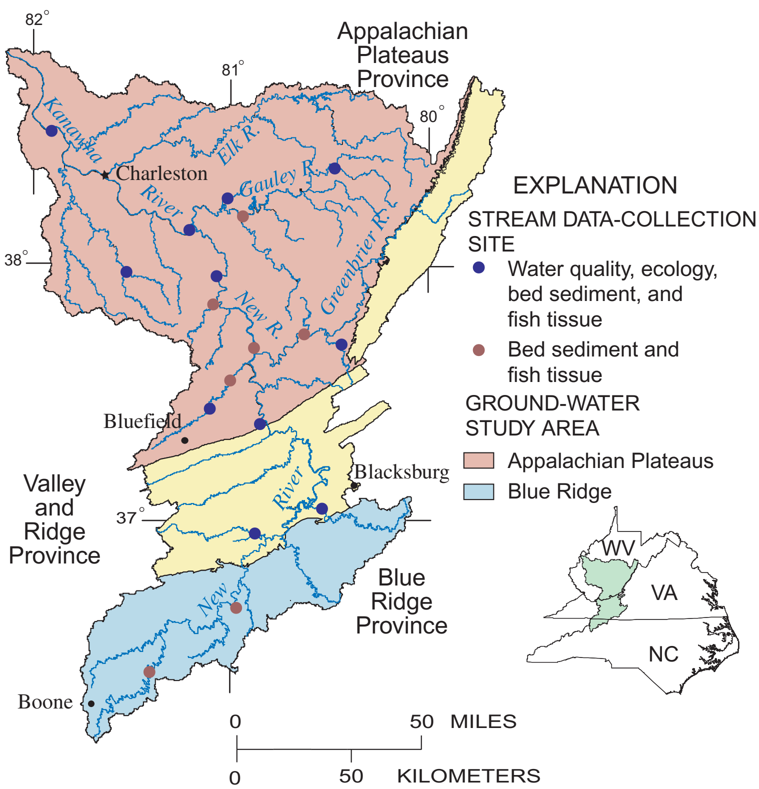
THIS REPORT summarizes major findings about water quality in the Kanawha–New River Basin that emerged from an assessment conducted between 1996 and 1998 by the U.S. Geological Survey (USGS) National Water–Quality Assessment (NAWQA) Program. Water quality is discussed in terms of local and regional issues and compared to conditions found in all 36 NAWQA study areas, called Study Units, assessed to date. Findings also are explained in the context of selected national benchmarks, such as those for drinking-water quality and the protection of aquatic organisms. The NAWQA Program was not intended to assess the quality of the Nation's drinking water, such as by monitoring water from household taps. Rather, NAWQA assessments focus on the quality of the resource itself, thereby complementing many ongoing Federal, State, and local drinking-water monitoring programs. Comparisons made in this report to drinking-water standards and guidelines are only in the context of the available untreated resource. Finally, this report includes information about the status of aquatic communities and the condition of instream habitats as elements of a complete water-quality assessment.

Many topics covered in this report reflect the concerns of officials of State and Federal agencies, water-resource managers, and members of stakeholder groups who provided advice and input during this water-quality assessment. Residents of West Virginia, Virginia, and North Carolina who wish to know more about water quality in the areas where they live will find this report informative as well.



THE NAWQA PROGRAM of the USGS seeks to improve scientific and public understanding of water quality in the Nation's major river basins and ground-water systems. Better understanding facilitates effective resource management, accurate identification of water-quality priorities, and successful development of strategies that protect and restore water quality. Guided by a nationally consistent study design and shaped by ongoing communication with local, State, and Federal agencies, NAWQA assessments support the investigation of local issues and trends while providing a firm foundation for understanding water quality at regional and national scales. The ability to integrate local and national scales of data collection and analysis is a unique feature of the USGS NAWQA Program.

The Kanawha–New River Basin is one of 51 water-quality assessments initiated since 1991, when the U.S. Congress appropriated funds for the USGS to begin the NAWQA Program. As indicated on the map, 36 assessments have been completed, and 15 more assessments will conclude in 2001. Collectively, these assessments cover about one-half of the land area of the United States and include water resources that are available to more than 60 percent of the U.S. population.



The Kanawha–New River Basin is generally mountainous, forested, humid, and rural. Agriculture is concentrated in the southern half of the basin; major products are cattle and hay. Seven percent of all coal mined in the United States is produced from the Appalachian Plateaus Physiographic Province within the basin.

Stream and River Highlights

The generally low population and intensity of agriculture and urban land uses throughout the Kanawha–New River Basin are reflected in low concentrations of nutrients and pesticides in streams and rivers.

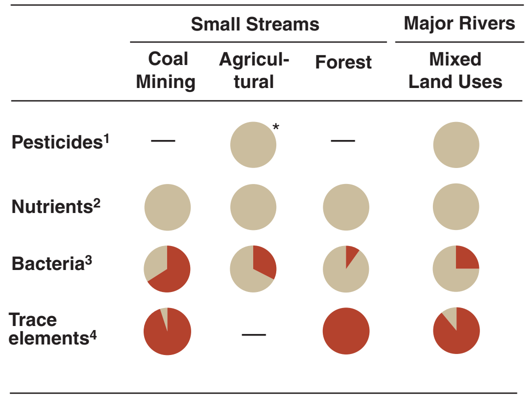
Streams in the coal region of the Appalachian Plateaus Physiographic Province generally improved between about 1980 and 1998 with respect to pH, total iron, total manganese, and sedimentation. These improvements were among the regulatory goals of the Surface Mining Control and Reclamation Act of 1977 (SMCRA). Other unregulated factors, however, show the effects of continued mining. Mine drainage in the basin is rarely acidic but has high concentrations of sulfate, which decrease slowly after mining ends. Stream-bottom sedimentation in mined basins remains greater than in undisturbed basins.

- Streams draining basins that have been mined since 1980 show increased dissolved sulfate, decreased median bed-sediment particle size, and impaired benthic-invertebrate communities compared to streams not mined since 1980. (p. 5–11)
- In all basins studied where more than 100,000 tons of coal per square mile have been mined, the stream benthic-invertebrate community is impaired in comparison to rural parts of the basin where less than 10,000 tons of coal per square mile have been mined since 1980. Some basins in which the benthic-invertebrate community is impaired, however, were not heavily mined. Benthic invertebrates are sensitive indicators of many types of disturbance and respond to impairment of either stream chemistry or physical habitat. (p. 7–8)
- Effects on stream benthic-invertebrate communities caused by coal mining were of similar magnitude to the effects caused by urban development and agriculture elsewhere in the Nation. (p. 11)
- Kanawha Falls is the upstream limit for the range of several fish species. Non-native fish continue to expand their range in tributaries of the New and Gauley Rivers. (p. 12–14)
- *Escherichia coli* (*E. coli*) bacteria concentrations exceeded the national guideline for public swimming areas in 26 percent of samples from major rivers and in 43 percent of samples from tributary streams, but no outbreak of waterborne disease was reported during 1991–98. Inadequate sewage treatment and manure management contribute to elevated *E. coli* concentrations. (p. 14–15)
- Volatile organic compounds (VOCs) continue to be detected in the Kanawha River downstream from the Charleston metropolitan area. (p. 16)
- Nickel, chromium, zinc, and certain toxic organic compounds were found in bed sediment in concentrations that could harm aquatic life. Elevated concentrations of cadmium, mercury, nickel, selenium, and zinc were measured in fish tissue at some sites. (p. 12)

Major Influences on Streams and Rivers

- Coal mining
- Improper disposal of human and animal wastes
- Past industrial activities

Selected Indicators of Stream-Water Quality



- Percentage of samples with concentrations **greater than or equal to** health-related national guidelines for drinking water, protection of aquatic life, or contact recreation; or above a national goal for preventing excess algal growth
- Percentage of samples with concentrations **less than** health-related national guidelines for drinking water, protection of aquatic life, or contact recreation; or below a national goal for preventing excess algal growth
- Percentage of samples with **no detection** (* Detected in 1 percent or less of samples)
- — Not assessed

[1] Insecticides, herbicides, and pesticide metabolites, sampled in water.
[2] Phosphorus and nitrogen, sampled in water.
[3] *Escherichia coli* (*E. coli*) bacteria, sampled in water.
[4] Nickel, chromium, zinc, and lead, sampled in streambed sediment.

Ground-Water Highlights

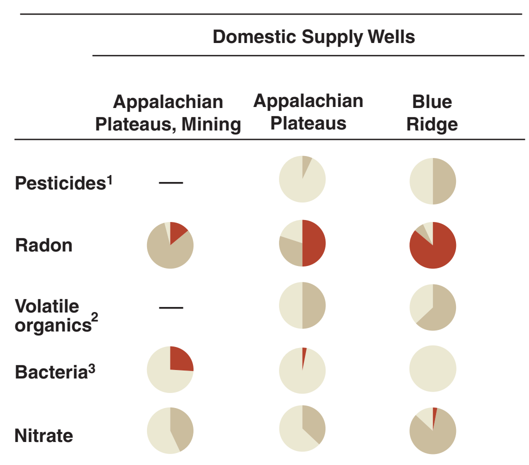
Ground water in the Appalachian Plateaus and Blue Ridge Physiographic Provinces moves mostly in a network of narrow fractures within a few hundred feet of the land surface, and drains toward the nearest stream. Wells normally tap only a few of the many local fractures. The ridgetops bound each local aquifer, which generally are affected only by local contaminant sources. In small areas of the basin where caves and solution cavities in limestone bedrock are common, wells can have high yields but are susceptible to contamination from fecal bacteria, pesticides, and other toxic chemicals.

- Radon concentrations in the Blue Ridge were among the highest in the Nation. Almost 90 percent of wells sampled there exceeded the proposed U. S. Environmental Protection Agency (USEPA) primary drinking-water standard of 300 picocuries per liter (pCi/L). One-third of these wells contained more than 4,000 pCi/L, the proposed alternate drinking-water standard. Radon is a radioactive gas that forms during the decay of natural uranium. (p. 18–19)
- Modern well construction can prevent fecal bacteria from reaching drinking water in most areas of the basin. Bacteria were frequently detected only at older wells. (p. 19)
- Potentially explosive concentrations of methane were found in water at 7 percent of wells in the coal region of the Appalachian Plateaus. (p. 17)
- Nutrients, pesticides, and VOCs were detected in low concentrations throughout the basin. In the Blue Ridge, however, water from more than 50 percent of wells contained pesticides, an indication that the ground water is vulnerable to contamination. (p. 19)
- In the Appalachian Plateaus, iron and manganese concentrations exceeded USEPA drinking-water guidelines in at least 40 percent of the wells and in about 70 percent of wells near reclaimed surface coal mines. Elevated sulfate concentration and slightly acidic water were more common at wells within 1,000 feet of reclaimed mines than elsewhere. (p. 10 and 17)

Major Influences on Ground Water

- Composition of soils and bedrock
- Improper disposal of human and animal wastes
- Current and past mining practices
- Pesticide usage and other toxic chemical releases

Selected Indicators of Ground-Water Quality



- Percentage of samples with concentrations **greater than or equal to** health-related national guidelines for drinking water
- Percentage of samples with concentrations **less than** health-related national guidelines for drinking water
- Percentage of samples with **no detection**
- — Not assessed

[1] Insecticides, herbicides, and pesticide metabolites, sampled in water.
[2] Solvents, refrigerants, fumigants, gasoline, and gasoline additives, sampled in water.
[3] Fecal coliform bacteria, sampled in water.

Population and Human Activities

The Kanawha River and its major tributary, the New River, drain 12,223 mi^2 in North Carolina, Virginia, and West Virginia (Messinger and Hughes, 2000). Most of the total basin population of 870,000 (1990 data) live in rural areas, and industrial and residential areas cover less than 5 percent of the total area in the basin (fig. 1). Only about 30 percent of the population live in towns larger than 10,000 people, including the 25 percent who live in the Charleston, W. Va., metropolitan area. The total population has not changed substantially since the 1950s, mostly because of emigration from rural parts of the basin to urban centers in the Midwest and the South.

The only major industrial area in the basin is along the terrace of the Kanawha River, within about 20 miles of Charleston (fig. 2). Chemical industry practices that profoundly polluted the Kanawha River during the 1950s and 1960s have changed, and discharge of pollutants to streams has greatly decreased, although bed sediment and fish remain contaminated with dioxin and other industrial chemicals (Henry, 1981; Kanetsky, 1988; West Virginia Division of Environmental Protection, 2000).

In the Kanawha–New River Basin, most coal is mined in the Appalachian Plateaus in West Virginia (McColloch, 1998). About 7 percent of the coal mined in the United States comes from the Kanawha–New River Basin (Fedorko and Blake, 1998; Messinger and Hughes, 2000). Most coal mined in the basin has a low sulfur content. Coal production has increased since passage of the Clean Air Act amendments of 1990, which mandated a reduction of sulfate emissions to decrease acid precipitation.

Physiography

The streams and rivers of the basin drain areas in three physiographic provinces: the Blue Ridge (17 percent), the Valley and Ridge (23 percent), and the Appalachian Plateaus (60 percent). In the Appalachian Plateaus, little of the land is flat, and most flat land is in the flood plains and terraces of streams.

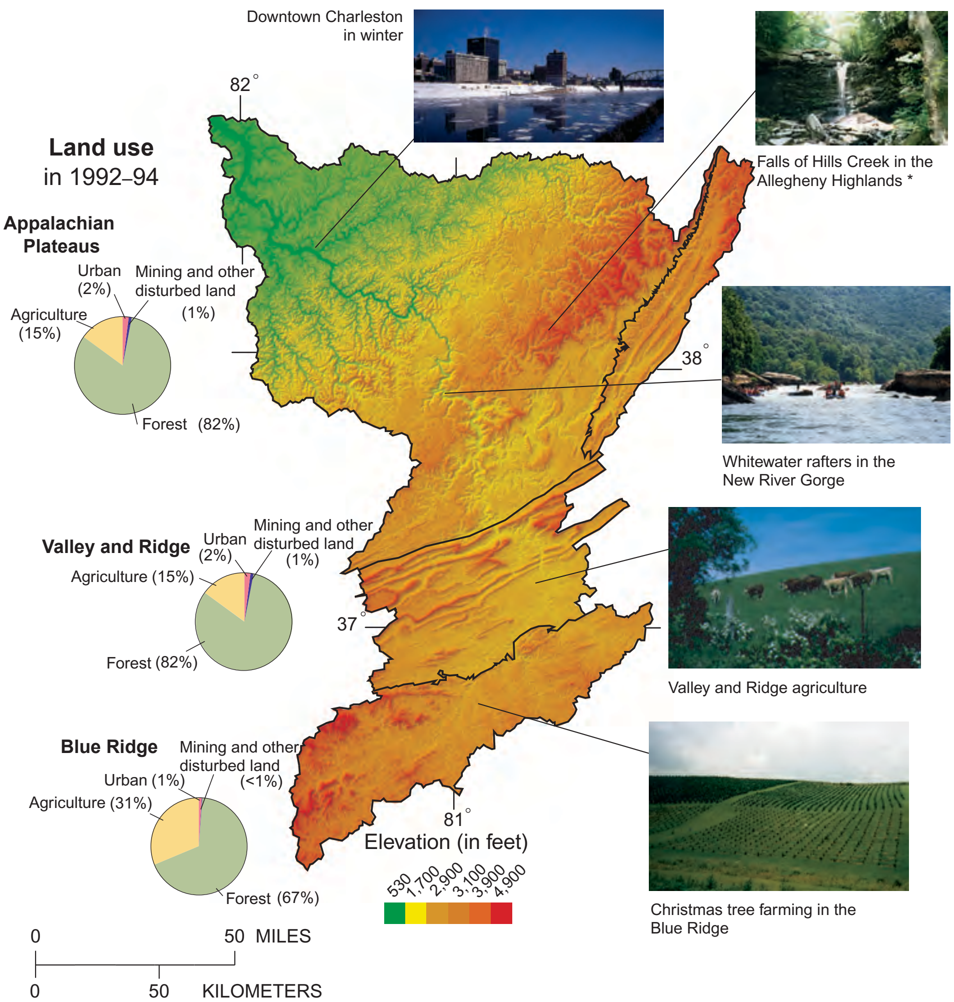


Figure 1. In the mountainous Kanawha–New River Basin, elevation ranges from over 4,000 feet in the Allegheny Highlands of the Appalachian Plateaus Province and the Blue Ridge Province to about 560 feet at the mouth of the river at Point Pleasant, W. Va. Forest accounted for 81 percent of the land cover in 1993 (Multi-Resolution Land Characteristics Interagency Consortium, 1997). Logging is a major industry throughout the basin. The entire basin was logged by the early 20th century, and no undisturbed areas remain (Clarkson, 1964). Coal mining is prevalent in the Appalachian Plateaus. The Blue Ridge Province contains proportionally more agricultural land than the Appalachian Plateaus and Valley and Ridge Provinces. Cattle, hay, and corn grown as cattle feed are the primary agricultural products (National Agriculture Statistics Service, 1999). Physiographic provinces from Fenneman, 1938.
** Photograph by Julie Archer, and used by permission.*

Figure 2. Coal and motor fuel commonly are transported by barge on the Kanawha River, downstream from Kanawha Falls.

The Valley and Ridge is characterized by strongly folded ridges separated by relatively flat, broad valleys. These two regions are underlain by sedimentary rocks. The Blue Ridge is characterized by igneous and metamorphic rocks that have been folded and faulted.

Water Use

In 1995, 61 percent of the basin's population depended on surface-water supplies for domestic needs (Solley and others, 1998). Thirty percent relied on domestic water wells. The remaining nine percent used public-supply water wells. In 1995, total withdrawal of water was about 1,130 Mgal/d (million gallons per day); total consumptive use was about 118 Mgal/d.

Hydrologic Conditions and Features

With some exceptions, mean streamflow during the study was within about 10 percent of long-term mean flows at most gaging stations (see records from a representative station in fig. 3). Major flooding occurred throughout the Appalachian Plateaus in January 1996, seven months before sampling began, and streamflow at several gaging stations within the Kanawha–New River Basin exceeded the 100-year flood flow (Ward and others, 1997). A thunderstorm in June 1998 caused flooding in the northwestern part of the basin where flow on a few small streams exceeded the 100-year recurrence interval (Ward and others, 1999). With the exception of these floods, no other flows exceeded the 10-year recurrence interval. No streams in the basin were in drought conditions during the study.

Streamflow varies most through the year in the western Appalachian Plateaus, and it varies least through the year in the Blue Ridge. On average, streamflow throughout the basin is greatest in February and March and least in September through October. Maximum streamflow does not coincide with maximum precipitation because summer vegetation uses a large fraction of the precipitation.

The river system in the Kanawha–New River Basin is regulated by four major flood-control dams, three navigation dams, and several smaller dams. The two largest dams are on the Gauley River (Summersville Dam) and Elk River (Sutton Dam). The other two major dams are on the New River. The navigable reach of the Kanawha River is in backwater caused by the navigation dams. In this reach, stream depth is greater and velocity is less than in the undammed reaches of the major rivers. All pools behind dams in the basin collect sediment. Dams are also major barriers to fish movement.

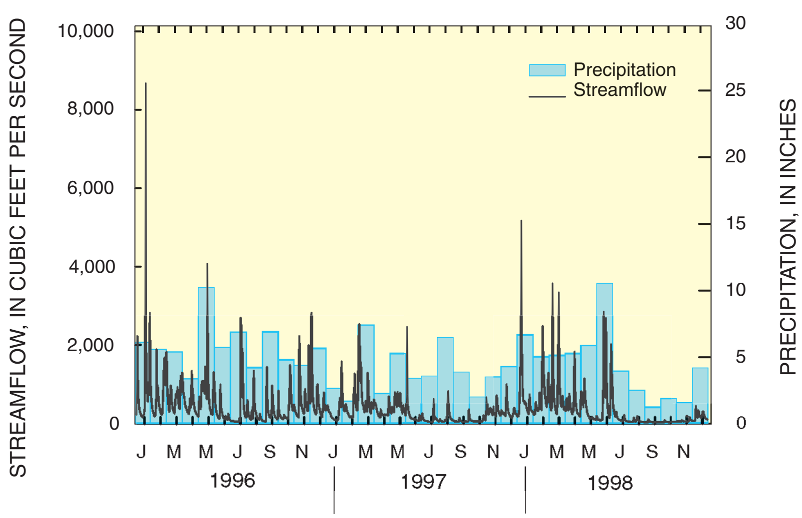


Figure 3. After a major flood in January 1996, streamflow from Williams River at Dyer, W. Va., and precipitation from Richwood, W. Va., were normal throughout the study period. The long-term average annual streamflow at Williams River at Dyer, W. Va. is 336 cubic feet per second. Long-term average precipitation at the Richwood, W. Va. location is 48 inches per year.

Persistent Changes in Water Chemistry and Aquatic Biology are Evident in Coal-Mined Areas

About 7 percent of all coal mined in the Nation comes from an area of 5,000 mi^2 in the Appalachian Plateaus part of the Kanawha–New River Basin. Production of the mostly low-sulfur coal nearly doubled from 1980 to 1998 as mining technology advanced, individual mines became larger, and employment decreased. Total production is about 90 million tons per year. A coal seam 1 foot thick and 1 mile square weighs about 1 million tons.

Most drainage basins within the coal region have been mined repeatedly as technology has advanced and economics have changed. Only three unmined basins greater than 10 mi^2 in the coal mining region were identified in this study. Among mined basins, cumulative coal production of less than 10,000 ton/mi^2 of coal during 1980–95 is low. Cumulative production in many basins ranged from 100,000 to 1,000,000 ton/mi^2.

Most water that drains from coal mines in the Kanawha–New River Basin is naturally neutral or alkaline rather than acidic.When iron pyrite in coal and adjacent rocks is exposed to air and water during mining, a series of chemical reactions produce dissolved iron and sulfuric acid (Rose and Cravotta, 1998). Natural or applied limestone, lye, or anhydrous ammonia can neutralize the acid (Skousen and others, 1998), but sulfate ions dissolved in water generally remain as evidence of the reactions. Sulfate concentrations in streams decrease slowly after mining ends (Sams and Beer, 2000).

Since 1981, Total Iron and Manganese have Decreased in Stream Basins where Coal Mining has Continued, but Sulfate has Increased

During low flow in July 1998, water samples from 57 wadeable streams (drainage area less than 1 to 128 mi^2) were analyzed once. Samples were collected from streams in the region of the Appalachian Plateaus where coal has been mined. At least three analyses were available for 51 of the sites for 1979–81, before the Surface Mining Control and Reclamation Act (SMCRA) affected regional water quality (Ehlke and others, 1982). Each 1998 analysis was compared to the one earlier analysis with the closest corresponding streamflow. Results were interpreted with respect to cumulative mining history and other land uses in each basin.

Median concentrations of total iron and total manganese were lower in 1998 than during 1979–81 in 33 basins that had been mined both before and after SMCRA, but sulfate concentration and specific conductance were higher (table 1). In 1998, median total manganese, specific conductance, sulfate, and pH were higher in 37 basins mined since 1980 than in 20 basins unmined since then; median total iron was lower in the mined basins, possibly reflecting aggressive treatment of permitted discharges.

Table 1. Medians of regulated constituents improved between 1979–81 and 1998 in 33 mined basins

[µg/L, micrograms per liter; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter]

	Median value	
	1979–81	1998
Regulated Constituents		
pH (standard units)	7.1	7.5
Total iron (µg/L)	455	150
Total manganese (µg/L)	150	78
Unregulated Constituents		
Specific conductance (µS/cm)	360	446
Sulfate (mg/L)	91	150

At the time the SMCRA and subsequent regulations were established, acidification and subsequent increase in metal concentrations, but not sulfate concentration, were known to degrade stream quality. Regulations,

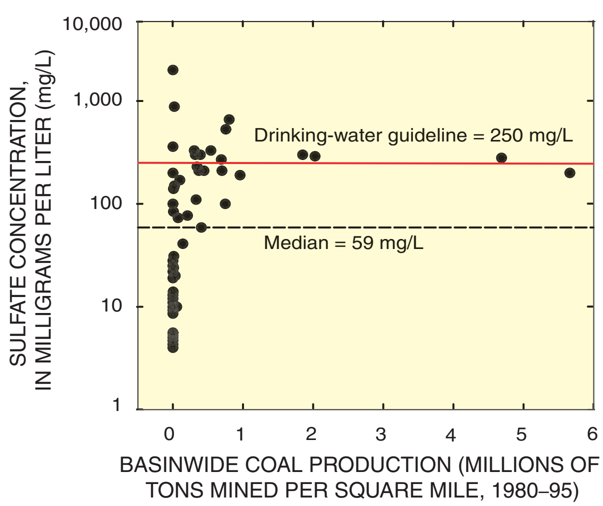


Figure 4. Sites with a low concentration of sulfate drained basins with little recent coal production. Sites with a high concentration of sulfate drained basins with a wide range of recent coal production.

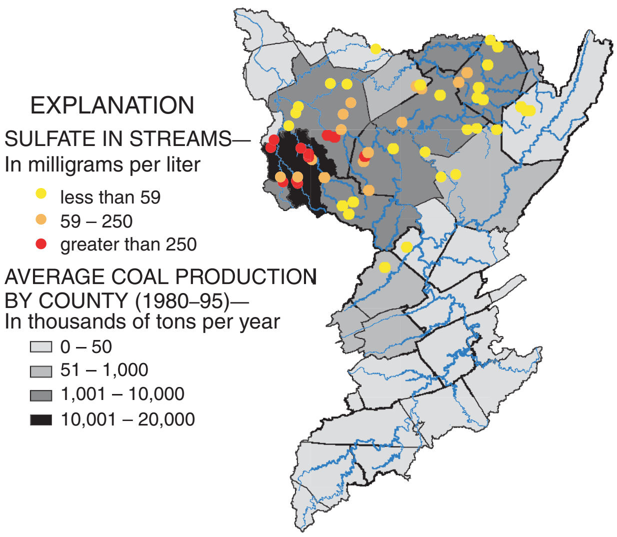


Figure 5. Sulfate concentration in wadeable streams was highest in counties with the highest coal production.

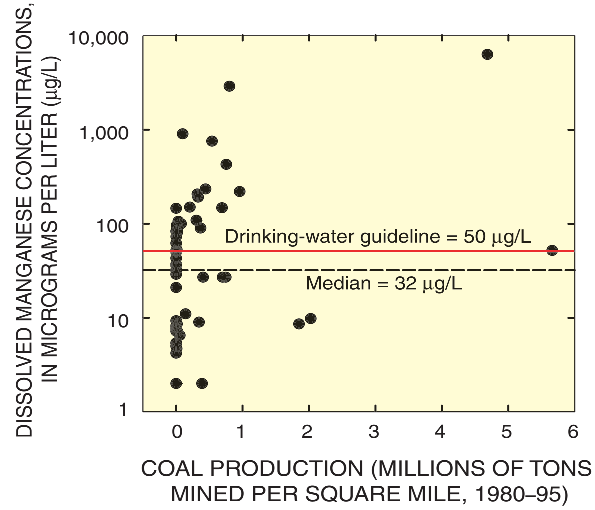


Figure 6. Concentrations of manganese in about half of the streams draining heavily mined basins were less than the study median.

therefore, were targeted at decreasing mining-related acidification and concentrations of iron and manganese, but were not designed to decrease sulfate concentrations. Sulfate concentrations less than 59 mg/L (milligrams per liter; study median) were measured only from basins where less than 142,000 ton/mi^2 of coal were produced during 1980–95 (figs. 4 and 5). In contrast, manganese concentrations less than 32 µg/L (micrograms per liter; study median) were measured at several heavily mined basins (fig. 6).

Sulfate concentration in streams draining mined areas does not correlate strongly with coal production because sulfate production depends on local geology, mining practice, and possibly results from activities in addition to mining. Sulfate concentration is higher than background, however, in basins with the greatest coal production. Background sulfate concentration was less than 25 mg/L in 16 of 20 basins not mined since 1980. In contrast, sulfate concentration was greater than 250 mg/L in 8 of 15 mined basins drained by streams tributary to the Coal River. The USEPA guideline for sulfate in drinking water is 250 mg/L.

For two years, water chemistry was analyzed monthly and at high flow at two streams in heavily mined basins, and at one stream where no coal had been mined since 1980. At the mined sites, sulfate, several other ions, and specific conductance decreased as streamflow increased; at the unmined site, major-ion concentrations were low at all flows (fig. 7). Dissolved iron and manganese concentrations were virtually unrelated to flow at all three sites. At both Peters Creek near Lockwood and Clear Fork at Whitesville, specific conductance was correlated with sulfate concentration, and correlations were nearly as strong between specific conductance and dissolved calcium, magnesium, sodium, and chloride. The same patterns were found in data for the sites before the implementation of the SMCRA.

Streamflow, water temperature, pH, and specific conductance were measured hourly at the two mined sites during the same two years. In the Coal River Basin at Clear Fork, sulfate concentration (estimated from the hourly specific conductance) exceeded the

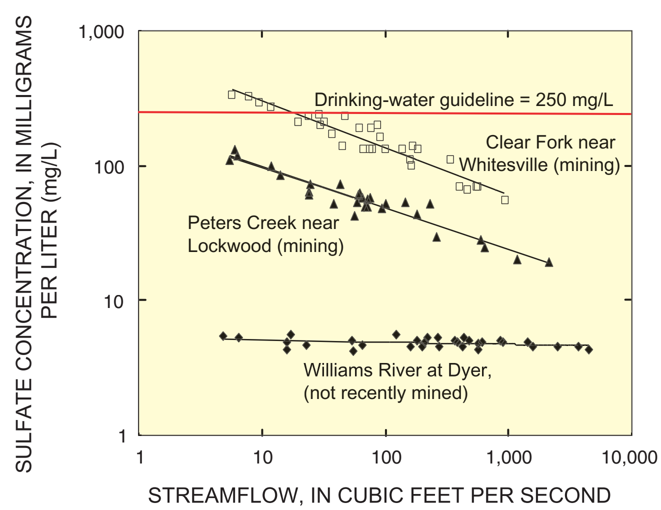


Figure 7. The concentration of sulfate, like other major ions, decreased with flow at two heavily mined sites but was consistently low at a site with no recent mining (Clear Fork $R^2 = 0.90$, Peters Cr $R^2 = 0.91$, Williams River $R^2 = 0.11$).

250-mg/L guideline about 25 percent of the time. Sulfate concentrations across a range of flow at Clear Fork were at least 10 percent greater in 1998 than in 1979–81.

Coal-mining methods in the Kanawha–New River Basin

In the Kanawha–New River Basin, half of the coal comes from underground mines and half from surface mines. Surface subsidence is expected above longwall mines, which remove about 90 percent of a coal seam, but is less common above room-and-pillar mines that may remove only 60 percent. Surface mines, both smaller contour mines and larger mountaintop mines, can remove 100 percent of a series of seams. Surface-mine operators working in steep-slope areas cannot simply replace all waste-rock material within the boundaries of the mine sites, because broken rock takes more space than consolidated rock. The excess is placed in valleys as fill material where the land is flat enough to provide a stable foundation, but the valley fills greatly affect the stream environment (U.S. Environmental Protection Agency, 2000).

Stream Benthic-Invertebrate Communities are Impaired at Mined Sites

In all streams sampled that drain areas where large quantities of coal have been mined, the benthic-invertebrate community is impaired in comparison to rural parts of the study area where little or no coal has been mined since 1980 (fig. 8). Some streams in which

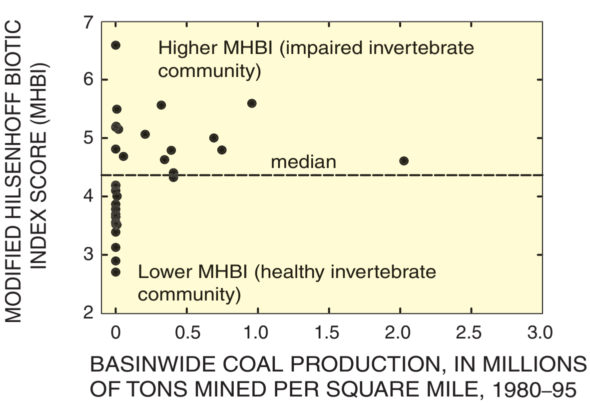


Figure 8. Only sites with little recent coal production had healthy invertebrate communities as measured by low (favorable) scores on the Modified Hilsenhoff Biotic Index, although not all impaired sites were in areas of high coal production.

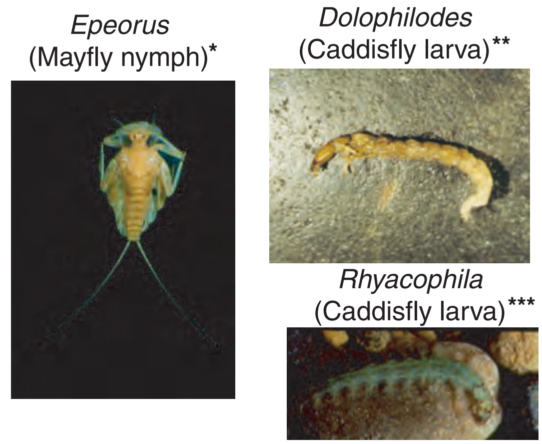


Figure 9. Invertebrates that are intolerant of fine sediment were present at unmined sites and sites with little coal production since 1980. (*Photograph by * Jennifer Hiebert, University of Alberta; ** D.B. Chambers, USGS; *** Arturo Elosegi, North American Benthological Society. All photos reproduced with permission*)

the community is impaired drained areas that were not heavily mined.

Invertebrate communities were sampled from riffles at 29 wadeable streams in areas of the Appalachian Plateaus where coal is or has been mined (Chambers and Messinger, 2001). The sites were separated into two groups by statistical comparison of species composition and abundance. Each group contained communities that were similar. The communities that included several insect taxa known for intolerance of fine sediment were identified as the less impaired group of sites. These taxa include *Epeorus* mayflies and *Dolophilodes* and *Rhyacophila* caddisflies (fig. 9). *Epeorus* is a genus of relatively large mayflies that cling to the bottom of large, loosely embedded rocks. Fine sediment can fill the openings in the stream bottom where they live. Caddisflies in the genus *Dolophilodes* spin finely meshed nets that can be clogged with silt. *Rhyacophila* are mobile predators typically found in clean, cool-water streams. These intolerant taxa were not present in the invertebrate communities at sites identified as poorer. In addition, scores from the MHBI (Modified Hilsenhoff Biotic Index; see glossary) and proportions of pollution-tolerant taxa from the midge family were significantly greater at the more impaired group of sites. The MHBI and other biological metrics are mathematical summaries of characteristics that change predictably in response to environmental stress. They are used to measure ecological health of a system (Karr and Chu, 1999).

Benthic invertebrates are good indicators of overall stream-water quality

Benthic invertebrates are sensitive indicators of many types of stream disturbance (Barbour and others, 1999). Because most have a life span of about a year and many remain in the same short section of stream during most of their lives, they are particularly well suited for assessments of short-term, local disturbances within a watershed. Fish, however, often move throughout a stream system, enabling them to seek refuge from such disturbances. An impaired invertebrate community is more than a disruption in the aquatic food web— it indicates that stream chemistry and (or) physical habitat are impaired. Stream-chemistry data provide useful information about the stream's quality only for the time of sampling, but benthic-invertebrate communities can show the effects of short-term disturbances that can easily be missed when stream-quality assessments rely only on chemical measurements.

Differences in land use, stream habitat, and stream chemistry between the groups of sites suggest possible causes for the different invertebrate communities. The less impaired group of sites drained basins that were unmined, or where less than 10,000 ton/mi^2 were mined during 1980–95. Most basins in the more impaired group of sites had been mined within the last 20 years by both surface and underground methods; most contained abandoned mines that pre-dated SMCRA and produced 100,000 to 1,000,000 ton/mi^2 of coal. Some of the basins in the more impaired group, however, had not been mined since 1980. Coal production during 1980–95 is not an ideal indicator of the environmental disturbance caused by coal mining, but it related better to environmental measurements than did production over a shorter interval, number of abandoned mines, or mine discharge permits (Chambers and Messinger, 2001).

At the more impaired sites, the proportion of total land area as strip mines, quarries, disturbed land, or gravel pits was significantly greater than at the less impaired sites. In addition, sulfate concentration, specific conductance, and alkalinity of stream water were all higher. Stream pH did not differ significantly between the two groups; pH is regulated in mine discharges.

Two basins that were not mined since 1980 contained valley fills similar to those constructed at large surface mines. The invertebrate community in Mill Creek near Hopewell, W. Va., which drains an area with few relatively small fills, grouped with the less impaired sites. Davis Creek at Trace Creek, W. Va., drains several large fills at a shopping center and was in the poorer group.

Instream habitat structure also differed significantly between the two groups. Sites from the less impaired group had less sand and silt in the stream bottom. Smaller median sediment size correlated with decreased number of taxa of mayflies, stoneflies, and caddisflies (EPT taxa) and an increased (more impaired) score on the Modified Hilsenhoff Biotic Index (fig. 10; $r^2 = 0.46$ and 0.43, respectively). Among the sites sampled, correlations between invertebrate metrics and coal production (or factors relating to coal mining) were weak, largely because some streams were impaired by other land uses. Erosion and sediment deposition in basins with active mines have decreased overall because of controls required under SMCRA, but temporal comparisons are not possible. Sedimentation in 1998 remained generally greater, however, at sites in basins with coal production since 1980 than in unmined basins.

The invertebrate-community degradation represented the cumulative effects of mining before and after SMCRA, deep mining and surface mining, mines in and out of compliance with applicable regulations, and all other nonmining disturbances in the basins. Impaired sites from this region ranked near the middle of an index that ranked NAWQA sites representing different land uses throughout the United States. (See discussion of effects on invertebrate communities nationally, p. 11). Logging and ongoing construction probably contribute to sedimentation, but their extent in each basin could not be quantified. Logging may contribute more sediment per disturbed volume of soil than mining.

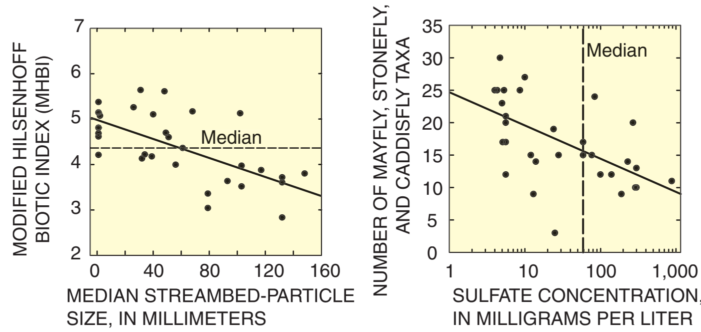


Figure 10. Invertebrate-community metrics show generally better conditions (lower MHBI) at sites with coarser streambeds and lower sulfate concentrations, although correlations are weak.

Regional study: Sulfate concentrations and biological communities in Appalachian coal fields indicated mining-related disturbances despite a general water-quality improvement between 1980 and 1998

In a 1998 study to assess regional water-quality effects of coal mining (Eychaner, 1999), samples representing the Northern Appalachian coal field were collected in the Allegheny and Monongahela River Basins (ALMN), where high-sulfur coal is common and acid mine drainage was historically severe, and samples for the Central Appalachian coal field were collected in the Kanawha–New River Basin (KANA), where acid drainage is uncommon (fig. 11).

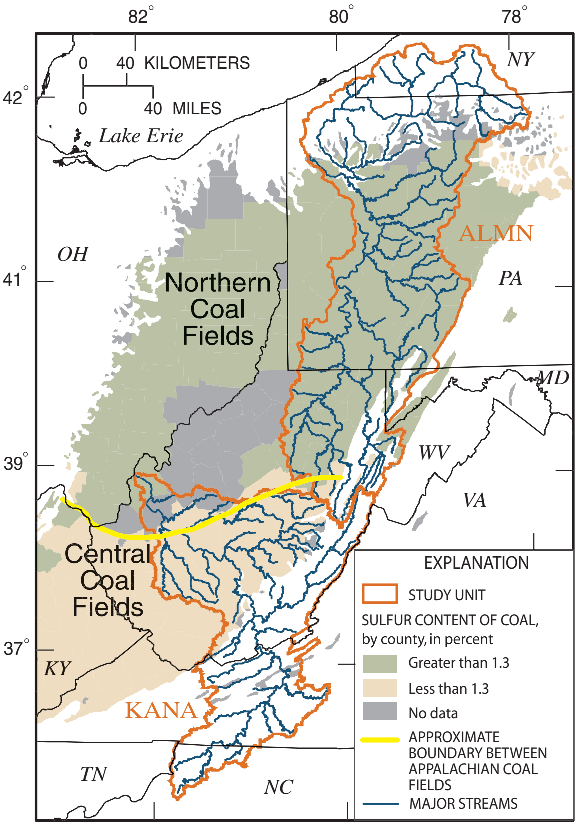


Figure 11. Coal seams in the Appalachian coal region vary in sulfur content, and the fields are identified primarily on the basis of this difference (Tully, 1996). The Kanawha–New River Basin contains mostly lower sulfur coal, while the Allegheny and Monongahela River Basins contain mostly higher sulfur coal.

Water chemistry in 178 wadeable streams was analyzed once during low flow, in July and August 1998. Drainage area for most streams was between 4 and 80 mi^2. Most (170) of these sites were also part of a study on the effects of coal mining that was conducted during 1979–81 (Herb and others, 1981a, 1981b; 1983; Ehlke and others, 1982), before regional water quality was affected by implementation of regulations from the Surface Mining Control and Reclamation Act (SMCRA). At 61 sites, aquatic invertebrates (insects, worms, crustaceans, and mollusks) also were collected. Ground water was sampled from 58 wells near coal surface mines and 25 wells in unmined areas. Wells sampled downgradient from reclaimed surface coal mines reflect the local effects of mining.

Concentrations of Regulated Constituents Improved in Stream Base Flow From About 1980 to 1998

During low-flow conditions, sulfate in more than 70 percent of samples from streams downstream from coal mines in both coal regions exceeded the regional background concentration. Background was calculated as about 21 mg/L sulfate from data for basins with no history of coal mining. The highest concentrations were measured in basins with the greatest coal production. One-fourth of all samples exceeded 250 mg/L, the USEPA drinking-water guideline.

Total iron, total manganese, and total aluminum also exceeded regional background concentrations (129, 81, and 23 µg/L, respectively) in many streams in mined basins. The median concentrations of total iron in the northern coal region were about equal between mined and unmined basins, but in the central region, concentrations of median total iron among mined basins were lower than among unmined basins. In both regions, median concentrations of total manganese among mined basins were about double that among unmined basins.

Median pH increased, and median concentrations of total iron and total manganese decreased among mined basins between 1979–81 and 1998 in both regions, reflecting that regulations restricting these constituents in mine drainage are effective. Even so, stream sites downstream from mines more commonly exceeded drinking-water guidelines for sulfate, iron, manganese, and aluminum concentrations than streams in unmined basins (fig. 12).

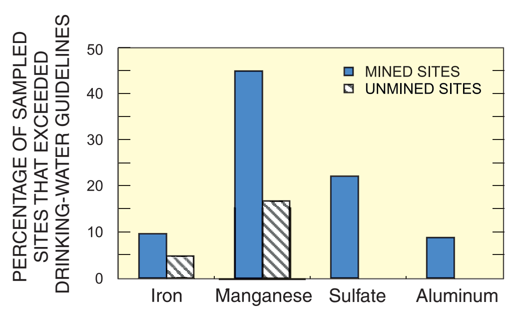


Figure 12. Stream water more often exceeded drinking-water guidelines at mined sites than at unmined sites.

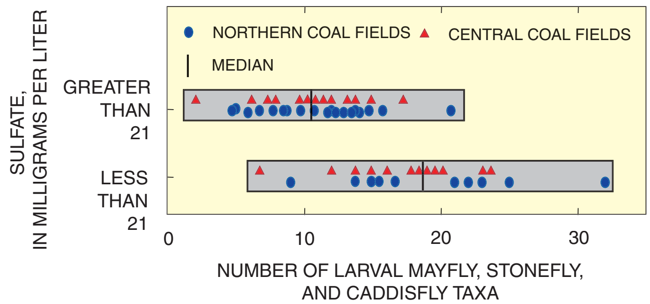


Figure 13. Sulfate concentration in stream water was inversely related to the number of mayfly, stonefly, and caddisfly taxa found at water-quality sampling sites.

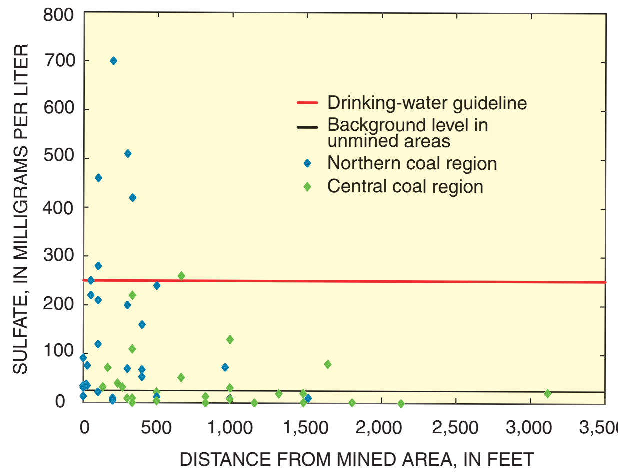


Figure 14. Sulfate concentrations in ground water are greater within 1,000 feet of reclaimed surface coal mines and in the northern coal region than at greater distance and in the central coal region.

Aquatic Benthic Invertebrate Communities are Impaired in Mined Basins

Aquatic invertebrate communities tended to be more impaired where there was more coal mining, when compared to basins where there was little coal mining. Pollution-tolerant species are more likely to be present at mined sites than at unmined sites, whereas pollution-sensitive taxa were fewer in number or non existent in heavily mined basins. Increasing coal production correlated with both an increased concentration of sulfate and a decline in some aquatic insect populations (fig. 13). Of the 61 sites where aquatic invertebrates were collected, those sites with sulfate concentrations higher than the estimated background concentration had the lower diversity of three groups of sensitive insect species (mayflies, stoneflies, and caddisflies), even though the pH of the water at all sites was greater than 6.5.

At the concentrations measured, the sulfate ion is relatively non toxic to aquatic organisms and may not represent the cause of the decline observed in mayflies and stoneflies. Sulfate concentration was, however, positively correlated with the total coal production from a basin (Sams and Beer, 2000). Other landscape disturbances associated with coal mining—changes in streamflow, siltation, or trace metal contamination—could affect the invertebrate community. Negative effects on communities caused by mining were of similar magnitude to the effects of urban development, agriculture, large construction projects, flow alterations, or wastewater effluent.

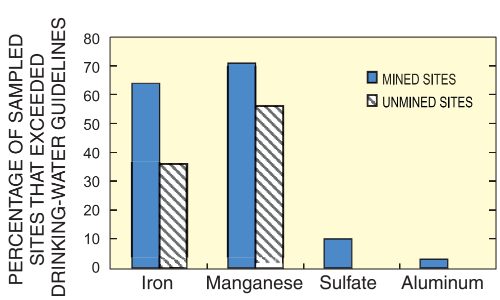


Figure 15. Ground-water samples more often exceeded drinking-water guidelines in mined areas than in unmined areas.

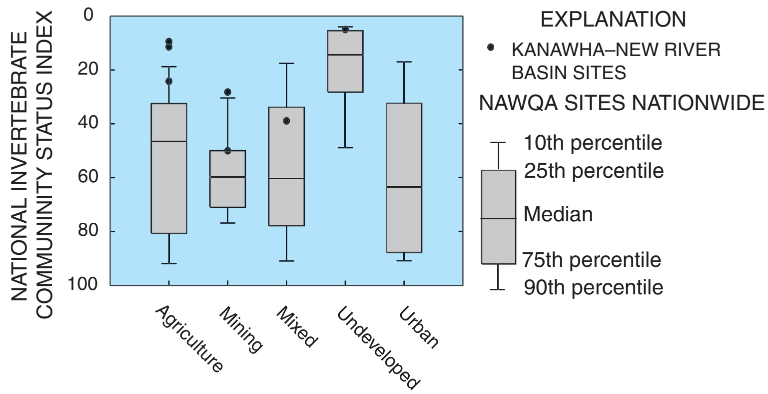
Sulfate, Iron, and Manganese Concentrations were Elevated in Wells Near Reclaimed Surface Mines

At mined sites in both coal regions, pH was lower and sulfate concentration was greater at mined sites than at unmined sites. Sulfate concentrations in ground water were higher than background concentrations in shallow wells within 1,000 feet of reclaimed surface mines (fig. 14). Samples from wells in the northern coal region contained more sulfate than wells at unmined sites in the same region, or at any of the sites in the central coal region. Iron, manganese, and aluminum were higher than background concentrations within about 2,000 feet of reclaimed surface mines (1,800, 640, and 11 µg/L, respectively).

Water from most wells, except at unmined sites in the northern coal region, exceeded guidelines for iron and manganese, which make the water unpleasant to drink (fig. 15). The concentrations in both regions were higher near reclaimed mines than at unmined sites.

Effects of mining on invertebrate communities were of similar magnitude to the effects caused by urban development and agriculture nationally

Invertebrate communities at two coal mining stream sites ranked near the middle of more than 600 NAWQA sites sampled nationwide during 1991–98. These sites had index scores better than national median scores for urban sites, about the same as national median scores for agricultural sites, and worse than national median scores for undeveloped sites. The community at a forested and undeveloped site in the Appalachian Plateaus was within the best 10 percent of NAWQA sites nationally and within the best 25 percent of undeveloped sites.



Sites in undeveloped and agricultural basins in the Kanawha–New River Basin rank among the best sites nationally in the National Invertebrate Community Status Index. More impaired sites in the Kanawha–New River Basin rank about the same or better than most sites that represent developed land uses nationally. (Low scores correspond to diverse invertebrate communities.)

Nationally, invertebrate communities at heavily agricultural sites were commonly highly impaired. In the Kanawha–New River Basin, agriculture is usually of low intensity and centers on pasturing small herds of cattle and growing cattle feed. Invertebrate communities at two agricultural sites, one in the Appalachian Plateaus and one in the Blue Ridge Physiographic Province, were within the best 10 percent of all sites nationally.

Some Contaminants are Widespread and Present at Potentially Harmful Concentrations in Streambed Sediment and Fish Tissue

Ten Polycyclic Aromatic Hydrocarbons were Found in Streambed Sediments in Concentrations that may Harm Aquatic Life

Forty samples of streambed sediment from 36 sites in the Kanawha–New River Basin were analyzed for polycyclic aromatic hydrocarbons (PAHs) during 1996–98. PAHs are components of wood smoke, diesel exhaust, soot, petroleum, and coal. Their toxicity varies, and some are carcinogenic to humans and other animals. Of the 12 PAHs for which guidelines were available, 10 were detected at concentrations exceeding the Probable Effect Level (PEL; see information box on sediment-quality guidelines), and all were detected at concentrations exceeding the Threshold Effect Level (TEL).

High concentrations of PAHs were present in each physiographic setting in the basin except for the Blue Ridge, although the only high concentrations in the Valley and Ridge/Appalachian Plateaus transition zone were in basins where coal has been mined. The highest PAH concentrations measured in this study were in the Appalachian Plateaus. Some of the highest PAH concentrations were measured at some of the most heavily mined sites in the basin, although the correlation between coal production and streambed PAH con-

Sediment Quality Guidelines

NAWQA's bed-sediment sampling protocol (Shelton and Capel, 1994) is designed to maximize the chance of detecting contaminants that have been transported in a stream during the previous 1–3 years. The data from this study were compared to final Canadian Sediment Quality Guidelines (SQGs) rather than the preliminary USEPA guidelines. SQGs have been issued by Environment Canada for 8 trace elements and 12 PAHs (Canadian Council of Ministers of the Environment, 1999). At concentrations below a Threshold Effect Level (TEL), contaminants are rarely expected to have a toxic effect on aquatic life. At concentrations above a Probable Effect Level (PEL), toxic effects are expected frequently. Concentrations of substances that exceed SQGs may imply, but not prove, that organisms in the streams of interest are at risk from those substances.

centration was weak ($r^2 = 0.52$, among 20 wadeable stream sites within the coal region). Coal samples from several commonly mined seams in West Virginia were between 20 and 85 percent PAH by mass (W.H. Orem, U.S. Geological Survey, written commun., July 2000). Coal particles are common in sediment from many streams in the coal fields. The PAHs from the coal particles, however, may not be bioavailable (Chapman and others, 1996). Unlike other NAWQA study areas, no correlation was found between most other land uses and PAH concentration.

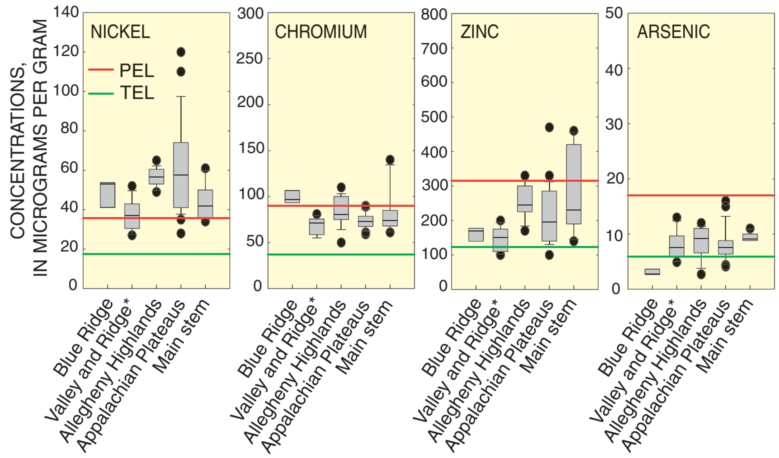


Figure 16. Some trace element concentrations in stream-bed sediment exceeded Environment Canada's effects-based criteria at several sites in the basin. Probable effects levels (PEL) are those concentrations at which harmful effects to aquatic life are thought to be likely, and were exceeded most frequently in the Allegheny Highlands and other Appalachian Plateaus streams. Threshold effects levels (TEL) were exceeded at all sites by nickel and chromium. *Valley and Ridge sites include transition zones between provinces.

Four Trace Elements were Present in Streambed Sediment in Concentrations That May Harm Aquatic Life

A total of 53 bed-sediment samples from 47 sites in the Kanawha–New River Basin were analyzed for trace elements during 1996–98. All eight of the trace elements for which criteria were available were found at some sites in concentrations exceeding their Threshold Effect Level (fig. 16; see information box on sediment-quality guidelines). Nickel, chromium, zinc, and lead were detected at concentrations exceeding their Probable Effect Level. Nickel concentrations exceeded the Probable Effect Level most frequently (in 47 of the 53 samples), based on the 1995 Sediment Quality Guidelines; a final SQG was not issued for nickel at the time that other SQGs were finalized.

Trace-element concentrations also were determined in livers of common carp or rock bass in 27 samples from 18 sites in 1996 and 1997. Some samples contained concentrations of arsenic, cadmium, lead, mercury, nickel, selenium, and zinc that were among the highest 25 percent of more than 900 NAWQA samples nationwide (1991–98). Concentrations of cadmium, mercury, nickel, selenium, and zinc in fish-tissue samples from the Kanawha–New River Basin ranked among the highest 10 percent of all NAWQA samples; six samples contained cadmium concentrations ranking among the highest 10 percent of all NAWQA samples, and five samples contained selenium concentrations ranking among the highest 10 percent of all NAWQA samples. One fish-tissue sample, from Kanawha River at Winfield, contained cadmium at a concentration ranking in the highest 1 percent of all samples in the Nation. Determining the human health or ecological significance of these concentrations is problematic, because tissue samples were collected from many different species and because fish-liver tissue is not normally eaten by humans.

Fish Communities Differ Considerably Throughout the Basin, but Non-native Species Continue to Expand Their Range

Fish communities in the Kanawha–New River Basin are complex and vary widely among streams of different size, physiographic setting, and land use. Individual species are distributed in patches, particularly upstream from Kanawha Falls (Jenkins and Burkhead, 1994). This patchy distribution can confound comparisons among streams (Strange, 1999). The quality of the regional fish community is generally good, although the national NAWQA fish index seems to underrate that quality because it does not consider the patchy distribution.

Non-native Fish Continue to Expand Their Range in Tributaries of the New and Gauley Rivers

Three fish species were collected for the first time at often-sampled sites in tributaries of the New and Gauley Rivers (Cincotta and others, 1999). Margined madtoms, a popular bait species, were collected for the first time from Second Creek near the village of Second Creek. Margined madtoms are native to some parts of the New River and some of its tributaries, but they had never before been collected from the Greenbrier River Subbasin. Telescope shiners (fig. 17), natives of the Tennessee River Basin, have been collected in the New River since 1958, and they continue to expand their range. Telescope shiners were collected from another often-sampled site, Williams River at Dyer, in the Gauley River Subbasin; this was their first collection upstream from Summersville Dam, a large impoundment. Telescope shiners also were collected for the first time from two Meadow River tributaries, also in the Gauley River Subbasin. Least brook lamprey were collected for the first time from Williams River at Dyer, their second collection from the Gauley River Subbasin. Populations of all these species were well established, and the ongoing expansion of their ranges suggests that all were relatively recent bait-bucket introductions to the New River system. Two of these reaches, and all of these streams, had been thoroughly sampled in the late 1970s (Hocutt and others, 1978, 1979).

Figure 17. Example of a telescope shiner (*Notropis telescopus*), a non-native species in the Kanawha–New River Basin. (Photograph from Jenkins and Burkhead, 1994; used by permission from the Virginia Department of Game and Inland Fisheries)

Other fish collected for the first time in the basin were in tributaries of the Coal River. The new species in Coal River distribution records were from large tributaries where few or no surveys had been made since the 1930s. Mottled sculpin, bluebreast darter, river carpsucker, blacknose dace, and longnose dace all were collected for the first time from Clear Fork near Whitesville or Spruce Laurel Fork at Clothier, major tributaries to the Big or Little Coal Rivers, respectively. Several of these records represented the most upstream collections in their respective forks of the Coal River, although all had been collected from the Coal River Subbasin. These new-species records most likely represent undersampling of streams that have often been overlooked by investigators rather than new range expansions.

In some regions of the United States, the highest proportion of non-native fish are typically present in the most impaired streams (Maret, 1997; Waite and Carpenter, 2000). In these regions, unimpaired streams are typically cold-water streams with complex physical habitat and low nutrient concentrations. In impaired streams where agricultural and urban land uses are common, stream temperature and nutrient concentrations are high and physical habitat is degraded. Many non-native fish tolerate these conditions better than many native species do, enabling the non-natives to displace the natives. No such relation was found in the Kanawha–New River Basin, where sedimentation and increased dissolved solids have impaired streams, but where temperature and nutrient concentrations have remained low (Messinger and Chambers, 2001, in press). The proportion of introduced fish in the New River system was high, even though other measures did not indicate impairment.

Fish Species Common Throughout the Ohio River Basin are Not Native Upstream from Kanawha Falls

The New River system, which fisheries biologists consider to include the Gauley River and its tributaries, supports a different collection of fish species than the downstream Kanawha River system, which is part of the larger Ohio River system (Jenkins and Burkhead, 1994). Kanawha Falls (see front cover), a 24-foot waterfall 2 miles downstream from the confluence of the New and Gauley Rivers, is the boundary between the New River and Kanawha River systems. This waterfall has been a barrier to upstream fish movement since glaciers affected streams more than 1 million years ago. The New River system lacks native species diversity, and it has unfilled ecological niches. It has only 46 native fishes and the lowest ratio of native fishes to drainage area of any river system in the Eastern United States.

The lack of native-species diversity allowed other species to develop in the New River system, which has the largest proportion of endemic species (found nowhere else in the world) in eastern North America (8 of 46). Introduced fish species have prospered in the New River system; Jenkins and Burkhead (1994) cite the New River system as having the largest number and proportion (42 of 89) of introduced freshwater species of all major eastern and central North American drainages.

Although many species have been introduced and become naturalized throughout the 19th and 20th centuries, the New River fish fauna remain susceptible to invasion. In contrast, 118 fish species are reported from the Kanawha River system downstream from Kanawha Falls (Stauffer and others, 1995); none of these fish species are endemic to the Kanawha River system, and only 15 are considered possible, probable, or known introductions.

Fish Communities are Controlled By a Variety of Environmental Factors in the Kanawha–New River Basin

In testing the possible effects of coal mining on fish communities, results were less definitive than for benthic invertebrates (p. 8–9). No common fish metrics (Karr and Chu, 1999; Barbour and others, 1999) correlated closely with mining intensity or its surrogate, sulfate concentration. The study included sites both upstream and downstream from Kanawha Falls, and differences in many metrics between the two groups mask differences among land-use categories (Messinger and Chambers, 2001, in press). However, fish were collected at only 13 wadeable sites in the coal region, which did not represent a full gradient of mining intensity.

High Concentrations of Fecal Bacteria Remain in Streams if Sources are Close

Concentrations of *Escherichia coli* (*E. coli*) exceeded the national guideline for public swimming areas in 26 percent of samples from major rivers in the Kanawha–New River Basin and in 43 percent of samples from tributary streams (fig. 18); however, no outbreak of waterborne disease was reported from the basin during 1991–98 (Barwick and others, 2000). Bacteria concentration in stream water varies widely, reflecting the changing balance between bacterial sources and many factors that help or hinder bacteria transport. Because of the wide variability, comparisons between streams based on only a few samples can be misleading; a few generalizations, however, can be made.

First, streams contain more bacteria if the sources are close to the stream and the sampling site. Among large rivers, median concentrations of *E. coli* were lowest in the New River Gorge at Thurmond, in a reach distant from any large city (fig. 18). Concentrations were highest in the Kanawha River downstream from the Charleston metropolitan area at Winfield. In the two tributary basins with the highest median concentrations, most homes are clustered close to the streams because the land slopes steeply elsewhere. In contrast, four tributary streams in basins with more moderate slopes, where bacteria sources are more dispersed, had median *E. coli* concentrations less than half as high. Regardless of slope, direct contamination of a stream by sewage or manure can produce extremely high concentrations, as Gillies and others (1998) observed in the Greenbrier River.

Second, bacteria concentrations exceeding guidelines are much more common when streamflow is greater than average, so streams generally contain more bacteria in winter than in summer (fig. 19). *E. coli* concentrations exceeded guidelines in less than one-third of summer samples from moderate-slope tributaries and less than one-fifth from large rivers. In the three

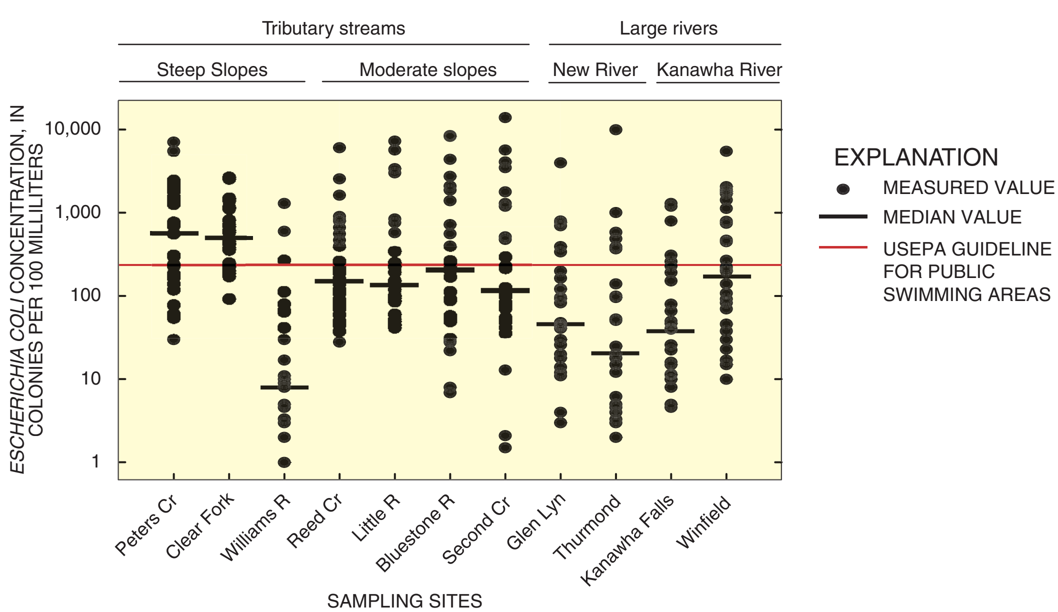


Figure 18. *E. coli* bacteria concentrations in streams vary widely.

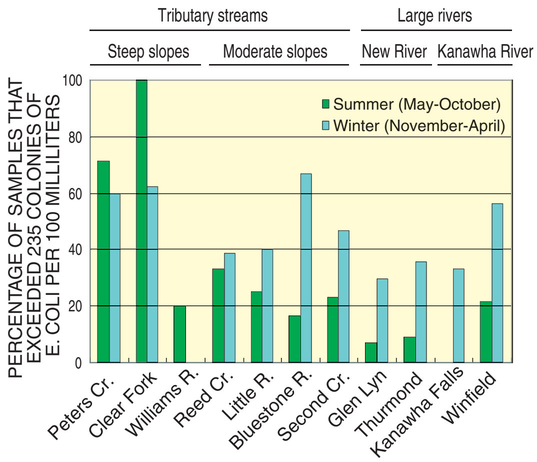


Figure 19. Guidelines for E. coli are exceeded more often in winter than in summer for most streams.

tributary basins with steeper slope, however, concentrations were higher in summer than winter.

Finally, streams contain more bacteria if the bacteria sources are large. Williams River, the tributary basin with the lowest median concentration of *E. coli* (fig. 18) is home to only 5 people per square mile, compared to the average of 71 people per square mile throughout the entire Kanawha–New River Basin. For twice the population density, median *E. coli* was about 300 percent higher among steep-slope tributaries. Among the moderate-slope basins, however, including the Bluestone River Basin with 201 people per square mile, median *E. coli* was only about 10 percent higher for twice the population density. Neither the estimated number of cattle nor the percentage of agricultural land use in the tributary basins showed a relation to the median bacteria concentrations.

Facts about *E. coli*

Escherichia coli (*E. coli*) is a bacterium that grows in the intestines of people, other mammals, and birds. Most strains of *E. coli* do not cause disease, but they do indicate water contamination by feces, which could contain other disease-causing organisms. The national guideline for public swimming areas is less than 235 *E. coli* colonies per 100 milliliters of water (col/100 mL) in any single sample (U.S. Environmental Protection Agency, 1986). That level is intended to allow no more than 8 gastrointestinal illnesses per 1,000 swimmers. For waters infrequently used for full-body-contact recreation, the guideline is 576 col/100 mL.

Nutrient and Organic-Chemical Concentrations in Surface Water are Low in Most of the Basin

Nutrients were Detected at Low Concentrations in Streams of the Kanawha–New River Basin

Mean concentrations of nutrients in the Kanawha–New River Basin were at or below national background levels. Most concentrations, however, exceed those measured at a stream-water-monitoring site at Williams River, which drains mostly National forest. The highest mean nitrate concentration measured was 1.5 mg/L. Flow-weighted mean ammonia concentrations ranged from less than 0.02 to 0.04 mg/L. Mean total phosphorus concentration was less than 0.1 mg/L at nine sites; the maximum was 0.15 mg/L. Nitrate and phosphorus are typically increased by agricultural or urban land uses, and certain nutrients, such as ammonia, can accumulate from natural sources.

Differences in nutrient concentrations were found among sites because of differences in land use/land cover, and physiography. Generally, basins with more agriculture produced more mean total nitrogen than did forested basins. The lowest mean total nitrogen concentration in streams, 0.71 mg/L was that for mostly forested tributary basins in the Appalachian Plateaus produced (fig. 20). The lowest mean concentration in the basin, or background concentration, was 0.45 mg/L, at Williams River. Tributary streams with basins mostly or wholly within the Valley and Ridge Physiographic Province had the highest mean total nitrogen, 1.04 mg/L. One stream in the Blue Ridge had a mean total nitrogen concentration of 0.94 mg/L. The mean total nitrogen concentration was not substantially different between large rivers and smaller tributaries (0.83 and 0.90 mg/L respectively).

Four sites, draining forest mixed with agriculture or coal mining, ranked among the best sites in the Nation in a national Algal Status Index. This index measures the proportion of algal samples that belong to species that are tolerant of high nutrient concentrations and siltation.

Pesticides were Detected at Low Concentrations in Surface Water

Pesticides were sampled for 9 to 25 times at four sites in 1997. Two sites were on main-stem, large streams. The other two sites on tributary streams drained basins with more than 30 percent agricultural

Figure 20. Because much of the Kanawha–New River Basin is forested, surface water and ground water contain low concentrations of nutrients and few pesticides.

land and some urban land. (See Study Unit Design, p. 20). Time of sampling covered the seasonal spectrum of both climate and pesticide application. The pesticides detected at all sites are routinely detected at agricultural sites across the Nation.

Surface-water samples in the Kanawha–New River Basin contained only a few pesticides at low levels. In all, 23 of 83 pesticides analyzed for were detected (Ward and others, 1998). All pesticide detections were less than 1 µg/L; concentrations detected did not exceed USEPA drinking-water standards or aquatic-life criteria. The most commonly detected pesticides were atrazine, deethylatrazine (a breakdown product of atrazine), metolachlor, prometon, simazine, and tebuthiuron. Atrazine, deethylatrazine, metolachlor and simazine were detected in more than 90 percent of samples.

Dioxin is a particularly toxic contaminant in certain herbicides formerly manufactured near Charleston and is a known contaminant in the lower Kanawha River, but it was not analyzed for this study. Dioxin in the lower Kanawha River is the target of ongoing regulatory investigations by USEPA and other agencies.

Many VOCs Detected in the Lower Kanawha River

Numerous volatile organic compounds (VOCs) have been detected routinely at low concentrations in the Kanawha River downstream from the Charleston metropolitan area (Tennant and others, 1992). In this study, more than 20 VOCs were detected, at concentrations ranging from 0.015 to 0.3 µg/L, in each of two samples collected in late 1997 from the Kanawha River at Winfield. Each sample was analyzed for 85 compounds (Ward and others, 1998). The compounds detected at Winfield, downstream from Charleston, included chloroform, motor fuel and aromatic compounds such as benzene, and industrial compounds such as ethers. In contrast, only a single compound was detected in one of two samples collected from the Kanawha River upstream at Kanawha Falls.

During 1987–96, one or more of 21 VOCs were detected in 50 percent of all daily samples collected for the Ohio River Valley Water Sanitation Commission (ORSANCO) from an industrial water intake at St. Albans, downstream from Charleston (Lundgren and Lopes, 1999). Benzene and toluene were the two most frequently detected compounds, and a maximum of 11 compounds was detected in a single sample. Median concentrations ranged from 0.1 to 2.3 µg/L. Gasoline spills or leaks of as little as 10 gallons per day that reach the river could produce the concentrations measured at St. Albans.

Radon Concentrations and Bacterial Contamination are the Principal Ground-Water-Quality Concerns

Physiographic Province, Geology, Well Construction, and Land Use Affect the Quality of Water from Domestic Wells

Ground water from private wells provides domestic supply for 30 percent of the people in the Kanawha–New River Basin. High concentrations of radon are a concern in the Blue Ridge (p. 18), and private wells can be contaminated by fecal bacteria throughout the basin (p. 19), but the occurrence of other contaminants differs among the physiographic provinces.

Appalachian Plateaus Physiographic Province

In the layered sedimentary rocks of the Appalachian Plateaus, ground water moves mostly in a network of narrow fractures within a few hundred feet of the land surface (Wyrick and Borchers, 1981; Harlow and LeCain, 1993). Individual fractures typically connect to only a few others, and a well normally taps only a few of the many fractures nearby. Recharge comes from rain and melting snow. Ground water flows generally toward the nearest stream, forming local aquifers bounded by the ridgetops. Contamination of a local aquifer and its stream is most likely to come from local sources.

Water samples were collected from 30 newer domestic wells or similar-capacity public-supply wells throughout the Appalachian Plateaus (Sheets and Kozar, 2000) and from 28 generally older domestic wells close to surface coal mines where reclamation was completed between 1986 and 1996. Wells near active mines were not sampled. Most of the wells were between 40 and 200 feet deep, and most water levels were between 10 and 90 feet below land surface.

Concentrations of iron and manganese exceeded USEPA drinking-water guidelines in 40 and 57 percent, respectively, of the wells throughout the Appalachian Plateaus and in about 70 percent of wells near reclaimed mines. Water that exceeds these guidelines is unpleasant to drink and can stain laundry and plumbing fixtures, but it is not a health hazard.

Potentially hazardous concentrations of methane, an odorless component of natural gas that is often associated with coal seams, were detected in water at 7 percent of the wells. At concentrations greater than about 10 mg/L, methane can bubble out of water pumped from a well. If enough gas collects in a confined space, an explosion is possible. In the West Virginia coal fields, any well water that bubbles is a potential methane explosion hazard.

Other chemical analyses of ground water samples collected as part of this study showed the following water-quality characteristics and conditions. Water from 61 percent of the wells near reclaimed mines was slightly acidic (pH less than 6.5) and could leach lead or copper from water pipes in homes. Only 23 percent of other Appalachian Plateaus wells produced acidic water. Radon exceeded the proposed USEPA standard at half the wells throughout the Appalachian Plateaus (p. 18). Water from half the wells exceeded 20 mg/L of sodium, the upper limit that USEPA suggests for people on a sodium-restricted diet. Arsenic in water from 7 percent of the wells exceeded the 10-µg/L standard set in January 2001, but none exceeded the previous 50-µg/L standard. Concentrations of radon, sodium, and arsenic were lower in wells near reclaimed mines than in wells remote from reclaimed mines. Home water-treatment techniques can remove lead, copper, sodium, and arsenic from drinking water.

Blue Ridge Physiographic Province

In the igneous and metamorphic bedrock of the Blue Ridge, as in the Appalachian Plateaus, ground water moves in a network of shallow fractures. Local aquifers generally drain toward the nearest stream (Coble and others, 1985).

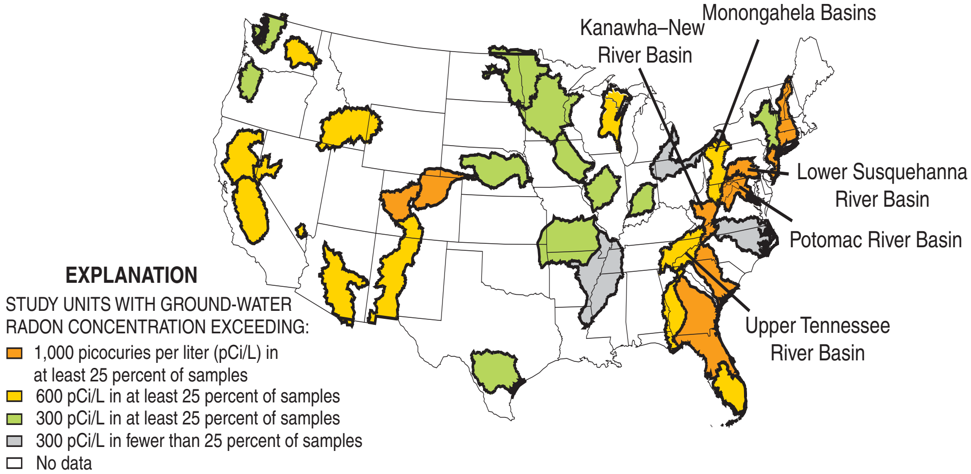
Water samples were collected from 30 newer domestic wells or similar low-capacity public-supply wells throughout the Blue Ridge. Most of the wells were between 100 and 350 feet deep, and most water levels were between 10 and 70 feet below land surface.

Ground water in the Blue Ridge is susceptible to contamination. Chlorofluorocarbon concentrations showed that the water in 89 percent of the wells had been recharged within the previous 20 years, indicating that contaminants could be transmitted readily into the fractured rock aquifers (Kozar and others, 2001).

Chemical analyses of ground water samples collected as part of this study indicated that concentrations of radon were among the highest in the Nation (p. 18); iron and manganese concentrations exceeded guidelines at only 17 percent of the wells; sodium exceeded 20 mg/L at 3 percent of the wells; and arsenic did not exceed 1 µg/L at any of the sites. Pesticides were detected at 57 percent of the wells. The presence of the common agricultural herbicide atrazine in ground water, even in low concentrations, shows that potential contaminants could move quickly from the land surface into the drinking-water aquifer.

Valley and Ridge Physiographic Province ground-water conditions can be inferred from studies in similar settings in the Potomac River Basin, which was one of the 1991 NAWQA study units. See Lindsey and Ator, 1996 and Ator and others, 1998 for more details.

Radon concentrations in ground water were among the highest in the Nation



Radon is a radioactive gas that forms during the decay of natural uranium. Igneous and metamorphic rocks, like those in the Blue Ridge, commonly contain more uranium than other rock types. Radon in the air in homes is the second leading cause of lung cancer; and radon causes 2–3 percent of all cancer deaths in the United States. Homes can be designed or remodeled to remove radon from both drinking water and interior air. The only way to determine if an individual well or home exceeds standards, however, is to have the water or air tested. Information on radon testing and removal is available at http://www.epa.gov/safewater/radon/qa1.html and other Web sites.

Radon concentration exceeds 1,000 pCi/L (picocuries per liter) in at least 25 percent of ground-water samples collected in many areas of the Eastern United States. In the Kanawha–New River Basin, 30 percent of samples exceeded 1,000 pCi/L (Appendix, p. 27), making the basin comparable to the Potomac and Lower Susquehanna River Basins to the northeast. Within the basin, however, radon in two-thirds of samples from wells in the Blue Ridge exceeded 1,000 pCi/L, but only in 10 percent of samples from the Appalachian Plateaus. The northern part of the basin, therefore, is more comparable to the adjacent Allegheny and Monongahela Rivers and Upper Tennessee River Basins.

Ground-water Radon Concentrations were Highest in the Blue Ridge

Radon concentrations were greater than 300 pCi/L, the proposed drinking-water standard (U.S. Environmental Protection Agency, 1999), in 87 percent of wells sampled in the Blue Ridge (fig. 21). The maximum concentration detected was 30,900 pCi/L (Kozar and Sheets, 1997). Of the 30 wells sampled, 10 contained concentrations of radon greater than 4,000 pCi/L, the alternate standard USEPA has proposed for regions where action is taken to decrease airborne radon. As water is used in a home, radon in the water can lead to an increase in radon in the air, which is the major exposure path for people.

Radon concentrations exceeded 300 pCi/L at 50 percent of wells sampled throughout the Appalachian Plateaus. The maximum in any sample was 2,500 pCi/L (fig. 21). The area is underlain primarily by sandstone, shale, coal, and limestone sedimentary rocks, in which uranium is less common than in igneous and metamorphic rocks.

At 28 wells downgradient from recently reclaimed surface coal mines, the median radon concentration was just 115 pCi/L, and the maximum was 450 pCi/L.

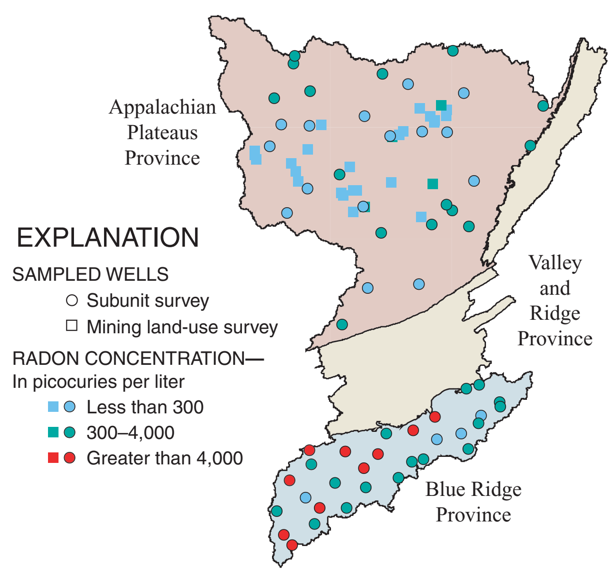


Figure 21. Radon concentrations vary greatly among physiographic provinces.

In comparison, at 15 wells in the same geologic units but not near mines, the median concentration was 200 pCi/L.

Modern Well Construction Can Prevent Fecal Bacteria from Reaching Drinking Water in Most Areas

Escherichia coli (E. coli) and the broader fecal coliform group of bacteria indicate the possible presence of disease-causing organisms. Standards for public drinking-water supplies do not permit the presence of any of these bacteria at detectable levels. Septic systems or livestock near a well are the probable sources of bacteria throughout the basin. Proper well construction can prevent bacteria from reaching the well water in some settings, and drinking water can be disinfected with chemicals or ultraviolet light.

Water from wells less than 25 years old in the Appalachian Plateaus and Blue Ridge was generally free from fecal bacteria (table 2). The sampled wells were generally in good condition, with a section of solid pipe at the top of the well sealed with concrete into the soil and rock (Sheets and Kozar, 1997). A residential septic system typically was nearby, but no heavy livestock use was within several hundred yards. Bacteria were found, however, at one fourth of the wells in a second study in the Appalachian Plateaus, which included some older wells and some without seals. Near these wells, there also may have been bacteria sources other than a septic system.

Table 2. *E. coli* or other fecal coliform bacteria were detected in few modern wells

Setting	Percentage of wells where bacteria were detected
Appalachian Plateaus:	
Newer wells	3
Older wells	26
Blue Ridge (newer wells only)	0

Most wells in limestone aquifers in the basin, including the Valley and Ridge, are at risk of contamination by bacteria (Boyer and Pasquarell, 1999), even if septic systems or livestock wastes are not nearby (Mathes, 2000), because ground water moves rapidly through solution channels in the rock. The wide valleys that typically overlie limestone aquifers are heavily used for livestock and agriculture.

Volatile Organic Compounds and Pesticides in Ground Water were Found in Low Concentrations

Both volatile organic compounds (VOCs) and pesticides were detected at low concentrations in the ground water of the Kanawha–New River Basin (Appendix, p. 27). Thirteen percent of samples (9 of 60) contained VOC concentrations greater than 0.1 µg/L. Of the seven detected VOCs, however, only three have established drinking-water standards. None of the VOCs identified in samples exceeded these standards. Pesticides were found above a detection limit of 0.001 µg/L in 32 percent of samples (19 of 60). Of the 12 detected pesticides, 4 have established drinking-water standards, none of which was exceeded.

Pesticides were detected in 17 of 30 wells sampled in the Blue Ridge, where 30 percent of the land was being used for agriculture in 1993. The most commonly detected pesticides, at one-third of the wells, were atrazine and its breakdown product deethylatrazine. The maximum concentration of all pesticides detected in a single sample was 0.14 µg/L. Two other pesticides, *p,p′*-DDE and simazine, were present in more than 10 percent of samples at a maximum concentration of 0.025 µg/L in this province. In the largely non agricultural Appalachian Plateaus, however, pesticides were detected only at two wells.

Nutrient Concentrations in Ground Water were At or Below National Background Levels

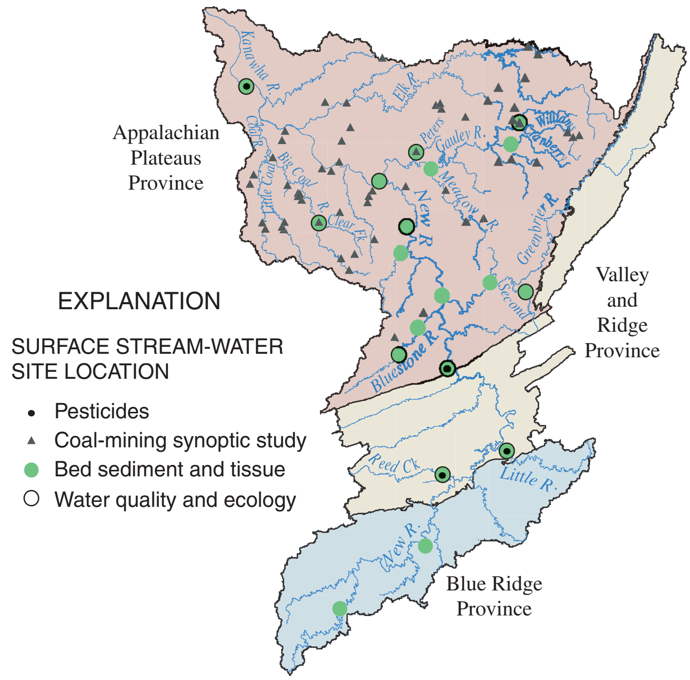
Nutrients were prevalent at relatively low concentrations in ground water of the Kanawha–New River Basin. Nitrate concentration in 1 of 88 wells sampled in this study exceeded the USEPA drinking-water standard of 10 mg/L (as nitrogen). Most ground water contained less nitrate than does precipitation in the basin. Concentrations of other nutrients measured were at or below national background levels. These findings are consistent with national findings on nutrients in the ground water of forested areas, and the Kanawha-New River Basin is about 80 percent forested.

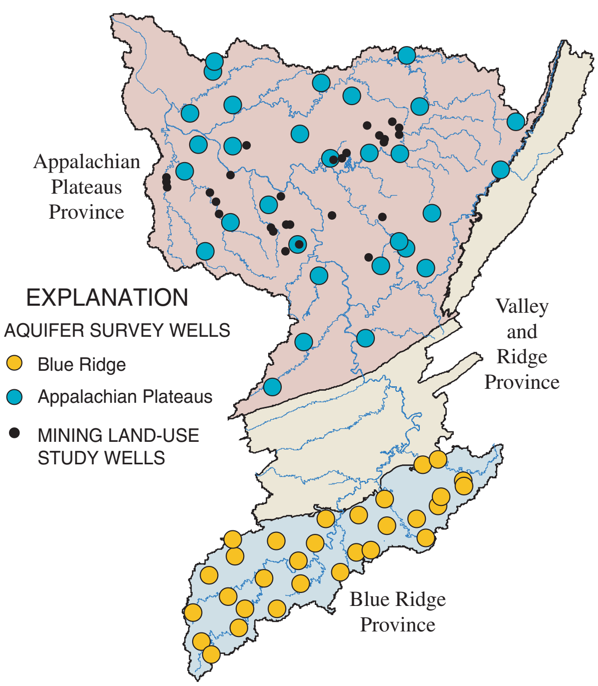
In the water of Appalachian Plateaus wells, the relatively high median ammonia concentration for a forested region–0.16 mg/L– is probably a result of mineralization of organic material. In contrast, ground water in the Blue Ridge, where a greater percentage of land is used for agriculture, had ground water with a higher median nitrate concentration (0.42 mg/L) and a higher median dissolved-oxygen concentration (5.1 mg/L).

Studies in the Kanawha–New River Basin were designed to describe the general quality of water and the aquatic ecosystem and to relate these conditions to natural and human influences (Gilliom and others, 1995). The design focused on the principal environmental settings—combinations of geohydrology, physiography, and land use—throughout the basin. The studies supplement assessment work by State agencies (Virginia Department of Environmental Quality, 1998; North Carolina Department of Environment and Natural Resources, 1999; West Virginia Division of Environmental Protection, 2000).

Stream Chemistry and Ecology

The sampling network was designed to characterize the effects of land use on stream quality at various scales. Water chemistry, fish and invertebrate communities, habitat, and bed-sediment and fish-tissue chemistry were used as indicators of stream quality. Fixed Sites were chosen on large rivers at the boundary between the Valley and Ridge and Appalachian Plateaus Physiographic Provinces, downstream from the Greenbrier and Gauley Rivers, and near the mouth of the Kanawha River. Fixed Sites also were chosen on tributaries to represent the effects of agriculture, coal mining, forest, and a relatively large human population in an otherwise rural setting.





Ground-Water Quality

The ground-water network was designed to broadly characterize the resource. Little previous information was available in the aquifer-survey areas. Aquifer surveys examined more constituents than any previous study and included a random component in site selection that allows estimates to be made for the whole population of similar wells. The land-use study targeted current effects of mining reclamation standards that have developed since around 1980.

Study component (Type of site)	What data were collected and why	Types of sites sampled	Number of sites	Sampling frequency and period
STREAM CHEMISTRY AND ECOLOGY				
Fixed sites—General quality of the water column	Concentration, seasonal variability, and load of major ions, common metals, nutrients, bacteria, organic carbon, dissolved oxygen, suspended sediment, pH, specific conductance, and temperature. Continuous streamflow monitoring.	Large rivers with mixed land use, draining 3,700 to 11,800 square miles at sites located between major tributaries or at boundaries of regional environmental settings.	4	Monthly plus storms: about 30 samples during October 1996 through September 1998.
		Tributary streams draining 40 to 300 square miles in basins with predominant land uses of agriculture, coal mining, forest, and rural residential.	7	
Fixed sites—Dissolved pesticides	Concentration and seasonal variability of 86 organic compounds in addition to the general water-column constituents listed above.	One large river downstream from the Valley and Ridge Physiographic Province and one near the mouth of the Kanawha River.	2	Semimonthly to monthly; 14 or 15 samples in 1997.
		Tributary streams with extensive agricultural land use.	2	Weekly to monthly during 1997; 9 or 25 samples.
Fixed sites—General stream ecology and habitat	Fish, benthic invertebrate, and algae communities were sampled and physical habitat was described to determine the presence and community structure of aquatic species.	Fixed sites where general water-column samples were collected.	11	Once, in 1997; three reaches sampled at each of three tributary sites in 1998.
Contaminants in fish tissue	To determine the presence of potentially toxic compounds in food chains that can include humans. Data included 22 elements and 28 organic compounds. Samples were a composite of at least five fish from one species, usually rock bass or common carp.	Fixed sites where general water-column samples were collected, plus contrasting settings in three large basins with mixed land use and five tributaries.	19	1 or 2 samples per site and species, during 1996 or 1997; 27 total samples.
Contaminants in bed sediment	To determine the presence of potentially toxic compounds attached to sediments accessible to aquatic life. Data included 44 elements and more than 100 organic compounds.	Same as sites for contaminants in fish. Composite samples were collected from depositional zones, where fine-grained sediments transported within the past year settle out of the water.	19	1 or 2 samples during 1996 or 1997; 21 total samples.
Synoptic sites—Coal mining	To assess the present effects of coal mining in Appalachian Plateaus streams and the change in stream chemistry since about 1980. Data included discharge, alkalinity, acidity, pH, specific conductance, sulfate, chloride, and dissolved and total iron, manganese, and aluminum. Coordinated with a similar study in the Allegheny-Monongahela study unit.	Streams draining 0.2 to 128 square miles in areas of known mining history, including unmined basins. Most of the sites were sampled for water-column chemistry during 1979–81.	57, including 3 Fixed Sites	One sample during low flow, July 1998.
	Benthic invertebrate community, physical habitat, contaminants in bed sediment, and other major ions in addition to constituents listed above.	A subset of sites described above, draining 8.8 to 128 mi^2.	30	
	Fish community, in addition to constituents listed above.	A subset of benthic invertebrate sites.	10	
GROUND-WATER				
Aquifer Surveys—Blue Ridge and Appalachian Plateaus	General water quality, to determine the occurrence and distribution of contaminants. Data included major ions, nutrients, bacteria, organic carbon, 19 trace elements, 47 pesticides, 86 volatile organic compounds, dissolved oxygen, turbidity, pH, specific conductance, and temperature. Samples from the Blue Ridge were analyzed for an additional 39 pesticides.	Domestic and public supply wells 25 years old and younger, and in good condition.	60	Once in 1997.
Land-use effects, reclaimed surface coal mines	General water quality, to determine effects of present reclamation requirements. Data included the constituents from aquifer surveys, without pesticides or volatile organic compounds. Coordinated with a similar study in the Allegheny-Monongahela Study Unit.	Domestic wells within 3,100 feet downgradient from a fully reclaimed surface coal mine. Reclamation was complete between 2 and 12 years before sampling. None of the sites were near "mountaintop removal" mines. Included both old and new wells.	28, compared to 10 unmined aquifer survey sites.	Once in 1998.

Aquatic-life criteria—Water-quality guidelines for protection of aquatic life. Often refers to U.S. Environmental Protection Agency water-quality criteria for protection of aquatic organisms.

Aquifer— A water-bearing layer of soil, sand, gravel, or rock that will yield usable quantities of water to a well.

Background concentration— A concentration of a substance in a particular environment that is indicative of minimal influence by human (anthropogenic) sources.

Bed sediment— The material that temporarily is stationary in the bottom of a stream or other watercourse.

Benthic— Of, related to, or occurring on the bottom of a water body.

Community— In ecology, the species that interact in a common area.

Constituent— A chemical or biological substance in water, sediment, or biota that can be measured by an analytical method.

Criterion— A standard rule or test on which a judgment or decision can be based. Plural, **Criteria.**

Cubic foot per second (ft^3/s, or cfs)— Rate of water discharge representing a volume of 1 cubic foot passing a given point during 1 second, equivalent to approximately 7.48 gallons per second, or 448.8 gallons per minute, or 0.02832 cubic meter per second.

Detection limit— The minimum concentration of a substance that can be identified, measured, and reported within 99 percent confidence that the analyte concentration is greater than zero; determined from analysis of a sample in a given matrix containing the analyte.

Dissolved constituent— Operationally defined as a constituent that passes through a 0.45-micrometer filter.

Dissolved solids— Amount of minerals, such as salt, that are dissolved in water; amount of dissolved solids is an indicator of salinity or hardness.

Downgradient— At or toward a location farther from the source of ground-water flow.

Drainage basin— The portion of the surface of the Earth that contributes water to a stream through overland runoff, including tributaries and impoundments.

Drinking-water standard or guideline— A threshold concentration in a public drinking-water supply, designed to protect human health. As defined here, standards are U.S. Environmental Protection Agency regulations that specify the maximum contaminate levels for public water systems required to protect the public welfare; guidelines have no regulatory status and are issued in an advisory capacity.

Escherichia coli—A common species of intestinal or fecal bacteria.

Fecal bacteria— Microscopic single-celled organisms (primarily fecal coliforms and fecal streptococci) found in the wastes of warm-blooded animals. Their presence in water is used to assess the sanitary quality of water for body-contact recreation or for consumption. Their presence indicates contamination by the wastes of warm-blooded animals and the possible presence of pathogenic (disease producing) organisms.

Intolerant organisms— Organisms that are not adaptable to human alterations to the environment and thus decline in numbers where human alterations occur. See also Tolerant species.

Major ions—Constituents commonly present in concentrations exceeding 1.0 milligram per liter. Dissolved cations generally are calcium, magnesium, sodium, and potassium; the major anions are sulfate, chloride, fluoride, nitrate, and those contributing to alkalinity, most generally bicarbonate and carbonate.

Maximum contaminant level (MCL)— Maximum permissible level of a contaminant in water that is delivered to any user of a public water system. MCLs are enforceable standards established by the U.S. Environmental Protection Agency.

Micrograms per liter (µg/L)— A unit expressing the concentration of constituents in solution as weight (micrograms) of solute per unit volume (liter) of water; equivalent to one part per billion in most streamwater and ground water. One thousand micrograms per liter equals 1 milligram per liter.

Milligrams per liter (mg/L)— A unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water; equivalent to one part per million in most streamwater and ground water.

Minimum reporting level (MRL)— The smallest measured concentration of a constituent that may be reliably reported using a given analytical method. In many cases, the MRL is used when documentation for the detection limit is not available.

Modified Hilsenhoff Biotic Index (MHBI)— The Hilsenhoff Biotic Index (HBI) is a benthic invertebrate community index developed by W.L. Hilsenhoff. The HBI is determined by assigning a pollution tolerance value for each family of benthic invertebrates, then computing the average tolerance for a sample. In a modification of the HBI developed by R.W. Bode and M.A. Novak, pollution tolerance values are assigned by genus, which provides greater resolution in the average tolerance.

Nutrient— In aquatic systems, a substance that contributes to algal growth. Nutrients of concern include nitrogen and phosphorus compounds, but not elemental nitrogen.

Picocurie (pCi)— One trillionth (10^{12}) of the amount of radioactivity represented by a curie (Ci). A curie is the amount of radioactivity that yields 3.7×10^{10} radioactive disintegrations per second (dps). A picocurie yields 2.22 disintegrations per minute (dpm), or 0.037 dps.

Polycyclic aromatic hydrocarbon (PAH)— A class of organic compounds with a fused-ring (aromatic) structure. PAHs result from incomplete combustion of organic carbon (including wood), municipal solid waste, and fossil fuels, as well as from natural or anthropogenic introduction of uncombusted coal and oil. PAHs include benzo(a)pyrene, fluoranthene, and pyrene.

Recharge— Water that infiltrates the ground and reaches the saturated zone.

Secondary maximum contaminant level (SMCL)— The maximum contamination level in public water systems that, in the judgment of the U.S. Environmental Protection Agency (USEPA), is required to protect the public welfare. SMCLs are secondary (nonenforceable) drinking water regulations established by the USEPA for contaminants that may adversely affect the odor or appearance of such water.

Sediment— Particles, derived from rocks or biological materials, that have been transported by a fluid or other natural process, suspended or settled in water.

Specific conductance— A measure of the ability of a liquid to conduct an electrical current.

Suspended (as used in tables of chemical analyses)— The amount (concentration) of undissolved material in a water-sediment mixture. It is associated with the material retained on a 0.45-micrometer filter.

Suspended sediment— Particles of rock, sand, soil, and organic detritus carried in suspension in the water column, in contrast to sediment that moves on or near the streambed.

Taxon— Any identifiable group of taxonomically related organisms, such as a species or family. Plural, **Taxa.**

Tolerant species— Those species that are adaptable to (tolerant of) human alterations to the environment and often increase in number when human alterations occur.

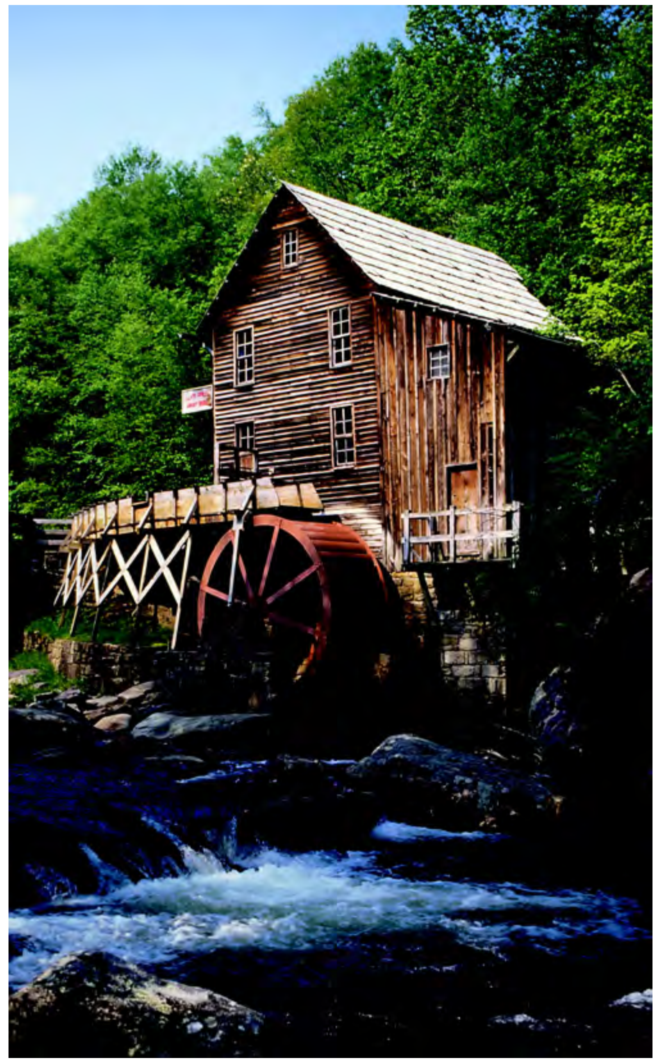
Trace element— An element found in only minor amounts (concentrations less than 1.0 milligram per liter) in water or sediment; includes arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc.

Upgradient— At or toward a location nearer to the source of ground-water flow.

Volatile organic compounds (VOCs)— Organic chemicals that have a high vapor pressure relative to their water solubility. VOCs include components of gasoline, fuel oils, and lubricants, as well as organic solvents, fumigants, some inert ingredients in pesticides, and some by-products of chlorine disinfection.

Water-quality standards— State-adopted and U.S. Environmental Protection Agency-approved ambient standards for water bodies. Standards include the use of the water body and the water-quality criteria that must be met to protect the designated use or uses.

Watershed— See Drainage basin.



Babcock Mill at Babcock State Park, WV.
Photograph by Douglas B. Chambers, USGS.

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Greenbrier River near Seebert, WV.
Photograph by Katherine S. Paybins, USGS.

APPENDIX—WATER-QUALITY DATA FROM THE KANAWHA–NEW RIVER BASIN IN A NATIONAL CONTEXT

For a complete view of Kanawha–New River Basin data and for additional information about specific benchmarks used, visit our Web site at http://water.usgs.gov/nawqa/. Also visit the NAWQA Data Warehouse for access to NAWQA data sets at http://water.usgs.gov/nawqa/data.

This appendix is a summary of chemical concentrations and biological indicators assessed in the Kanawha–New River Basin. Selected results for this basin are graphically compared to results from as many as 36 NAWQA Study Units investigated from 1991 to 1998 and to national water-quality benchmarks for human health, aquatic life, or fish-eating wildlife. The chemical and biological indicators shown were selected on the basis of frequent detection, detection at concentrations above a national benchmark, or regulatory or scientific importance. The graphs illustrate how conditions associated with each land use sampled in the Kanawha–New River Basin compare to results from across the Nation, and how conditions compare among the several land uses. Graphs for chemicals show only detected concentrations and, thus, care must be taken to evaluate detection frequencies in addition to concentrations when comparing study-unit and national results. For example, simazine concentrations in Kanawha–New River Basin agricultural streams were similar to the national distribution, but the detection frequency was much higher (94 percent compared to 61 percent).

CHEMICALS IN WATER

Concentrations and detection frequencies, Kanawha–New River Basin, 1996–98—Detection sensitivity varies among chemicals and, thus, frequencies are not directly comparable among chemicals

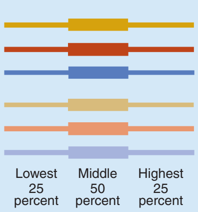
◆ Detected concentration in Study Unit

66 38 Frequencies of detection, in percent. Detection frequencies were not censored at any common reporting limit. The left-hand column is the study-unit frequency and the right-hand column is the national frequency

-- Not measured or sample size less than two

12 Study-unit sample size. For ground water, the number of samples is equal to the number of wells sampled

National ranges of detected concentrations, by land use, in 36 NAWQA Study Units, 1991–98—Ranges include only samples in which a chemical was detected



National water-quality benchmarks

National benchmarks include standards and guidelines related to drinking-water quality, criteria for protecting the health of aquatic life, and a goal for preventing stream eutrophication due to phosphorus. Sources include the U.S. Environmental Protection Agency and the Canadian Council of Ministers of the Environment

| Drinking-water quality (applies to ground water and surface water)

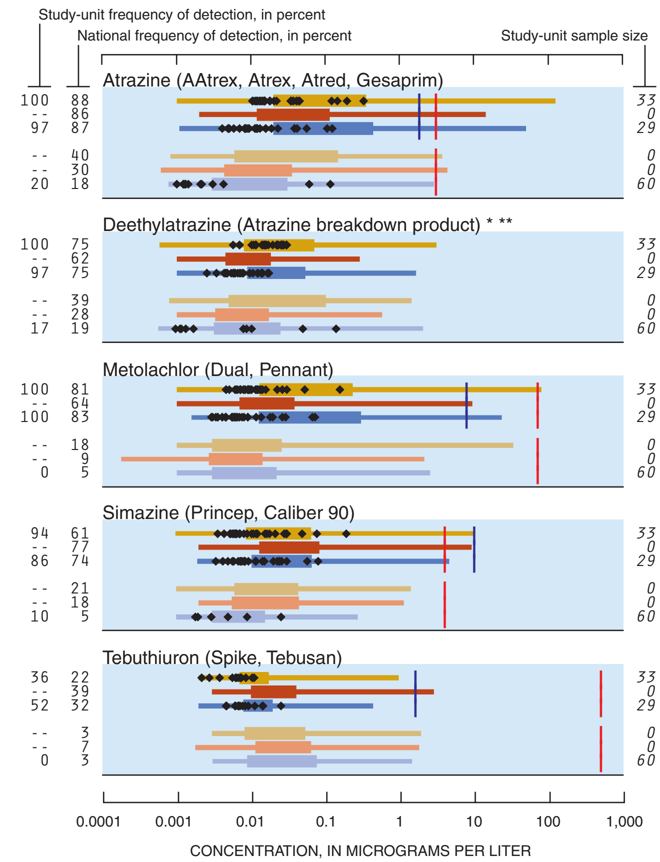
| Protection of aquatic life (applies to surface water only)

| Prevention of eutrophication in streams not flowing directly into lakes or impoundments

* No benchmark for drinking-water quality

** No benchmark for protection of aquatic life

Pesticides in water—Herbicides

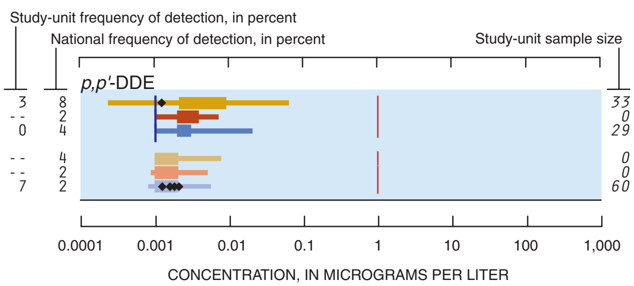


Other herbicides detected
Acetochlor (Harness Plus, Surpass) * **
Alachlor (Lasso, Bronco, Lariat, Bullet) **
Benfluralin (Balan, Benefin, Bonalan) * **
Cyanazine (Bladex, Fortrol)
DCPA (Dacthal, chlorthal-dimethyl) * **
2,6-Diethylaniline (Alachlor breakdown product) * **
Dinoseb (Dinosebe)
Diuron (Crisuron, Karmex, Diurex) **
EPTC (Eptam, Farmarox, Alirox) * **
Fenuron (Fenulon, Fenidim) * **
Molinate (Ordram) * **
Napropamide (Devrinol) * **
Oryzalin (Surflan, Dirimal) * **
Prometon (Pramitol, Princep) **
Triallate (Far-Go, Avadex BW, Tri-allate) *
Triclopyr (Garlon, Grandstand, Redeem, Remedy) * **
Trifluralin (Treflan, Gowan, Tri-4, Trific)

Herbicides not detected
Acifluorfen (Blazer, Tackle 2S) **
Bentazon (Basagran, Bentazone) **
Bromacil (Hyvar X, Urox B, Bromax)
Bromoxynil (Buctril, Brominal) *
Butylate (Sutan +, Genate Plus, Butilate) **
Chloramben (Amiben, Amilon-WP, Vegiben) **
Clopyralid (Stinger, Lontrel, Transline) * **
2,4-D (Aqua-Kleen, Lawn-Keep, Weed-B-Gone)
2,4-DB (Butyrac, Butoxone, Embutox Plus, Embutone) * **
Dacthal mono-acid (Dacthal breakdown product) * **
Dicamba (Banvel, Dianat, Scotts Proturf)
Dichlorprop (2,4-DP, Seritox 50, Lentemul) * **
Ethalfluralin (Sonalan, Curbit) * **

Fluometuron (Flo-Met, Cotoran) **
Linuron (Lorox, Linex, Sarclex, Linurex, Afalon) *
MCPA (Rhomene, Rhonox, Chiptox)
MCPB (Thistrol) * **
Metribuzin (Lexone, Sencor)
Neburon (Neburea, Neburyl, Noruben) * **
Norflurazon (Evital, Predict, Solicam, Zorial) * **
Pebulate (Tillam, PEBC) * **
Pendimethalin (Pre-M, Prowl, Stomp) * **
Picloram (Grazon, Tordon)
Pronamide (Kerb, Propyzamid) **
Propachlor (Ramrod, Satecid) **
Propanil (Stam, Stampede, Wham) * **
Propham (Tuberite) **
2,4,5-T **
2,4,5-TP (Silvex, Fenoprop) **
Terbacil (Sinbar) **
Thiobencarb (Bolero, Saturn, Benthiocarb) * **

Pesticides in water—Insecticides

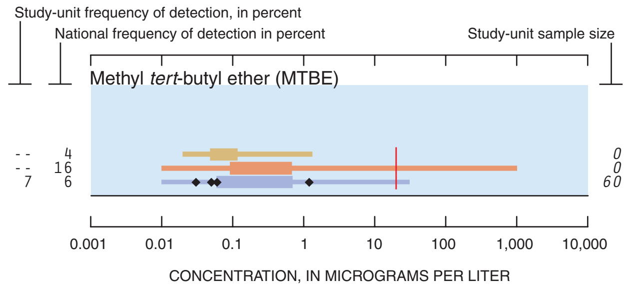


Other insecticides detected
Carbaryl (Carbamine, Denapon, Sevin)
Carbofuran (Furadan, Curaterr, Yaltox)
Chlorpyrifos (Brodan, Dursban, Lorsban)
Diazinon (Basudin, Diazatol, Neocidol, Knox Out)
alpha-HCH (alpha-BHC, alpha-lindane) **
gamma-HCH (Lindane, gamma-BHC)
Malathion (Malathion)

Insecticides not detected
Aldicarb (Temik, Ambush, Pounce)
Aldicarb sulfone (Standak, aldoxycarb)
Aldicarb sulfoxide (Aldicarb breakdown product)
Azinphos-methyl (Guthion, Gusathion M) *
Dieldrin (Panoram D-31, Octalox, Compound 497)
Disulfoton (Disyston, Di-Syston) **
Ethoprop (Mocap, Ethoprophos) * **
Fonofos (Dyfonate, Capfos, Cudgel, Tycap) **
3-Hydroxycarbofuran (Carbofuran breakdown product) * **
Methiocarb (Slug-Geta, Grandslam, Mesurol) * **
Methomyl (Lanox, Lannate, Acinate) **
Methyl parathion (Penncap-M, Folidol-M) **
Oxamyl (Vydate L, Pratt) **
Parathion (Roethyl-P, Alkron, Panthion, Phoskil) *
cis-Permethrin (Ambush, Astro, Pounce) * **
Phorate (Thimet, Granutox, Geomet, Rampart) * **
Propargite (Comite, Omite, Ornamite) * **
Propoxur (Baygon, Blattanex, Unden, Proprotox) * **
Terbufos (Contraven, Counter, Pilarfox) **

Volatile organic compounds (VOCs) in ground water

These graphs represent data from 16 Study Units, sampled from 1996 to 1998

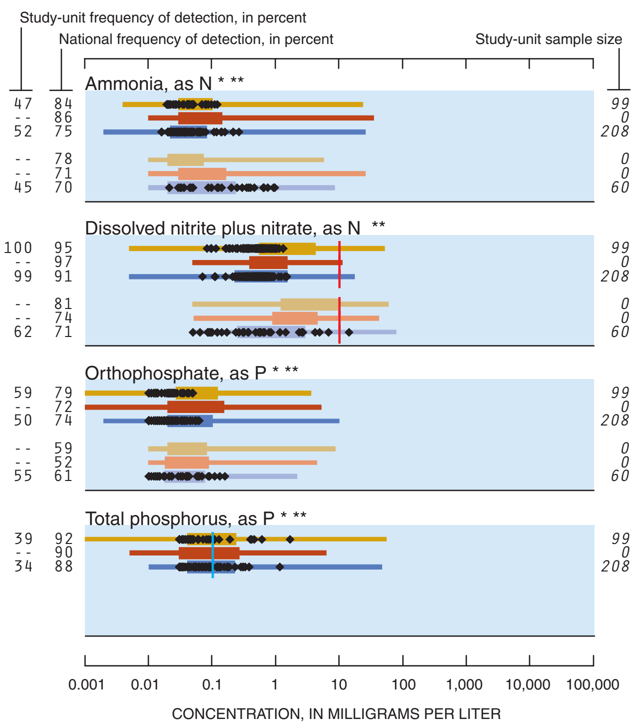


Other VOCs detected
Benzene
Bromodichloromethane (Dichlorobromomethane)
2-Butanone (Methyl ethyl ketone (MEK)) *
Carbon disulfide *
Chlorodibromomethane (Dibromochloromethane)
Chloromethane (Methyl chloride)
1,4-Dichlorobenzene (*p*-Dichlorobenzene)
Dichlorodifluoromethane (CFC 12, Freon 12)
1,1-Dichloroethane (Ethylidene dichloride) *
1,1-Dichloroethene (Vinylidene chloride)
cis-1,2-Dichloroethene ((Z)-1,2-Dichloroethene)
Diisopropyl ether (Diisopropylether (DIPE)) *
1,2-Dimethylbenzene (*o*-Xylene)
1,3 & 1,4-Dimethylbenzene (*m*-&*p*-Xylene)
1-4-Epoxy butane (Tetrahydrofuran, Diethylene oxide) *
Ethylbenzene (Phenylethane)
Iodomethane (Methyl iodide) *
Isopropylbenzene (Cumene) *
Methylbenzene (Toluene)
2-Propanone (Acetone) *
Tetrachloroethene (Perchloroethene)
Tribromomethane (Bromoform)
1,2,4-Trichlorobenzene
1,1,1-Trichloroethane (Methylchloroform)
Trichloroethene (TCE)
Trichlorofluoromethane (CFC 11, Freon 11)
Trichloromethane (Chloroform)
1,2,4-Trimethylbenzene (Pseudocumene) *

VOCs not detected
tert-Amylmethylether (*tert*-amyl methyl ether (TAME)) *
Bromobenzene (Phenyl bromide) *
Bromochloromethane (Methylene chlorobromide)
Bromoethene (Vinyl bromide) *
Bromomethane (Methyl bromide)
n-Butylbenzene (1-Phenylbutane) *
sec-Butylbenzene *
tert-Butylbenzene *
3-Chloro-1-propene (3-Chloropropene) *
1-Chloro-2-methylbenzene (*o*-Chlorotoluene)
1-Chloro-4-methylbenzene (*p*-Chlorotoluene)
Chlorobenzene (Monochlorobenzene)
Chloroethane (Ethyl chloride) *
Chloroethene (Vinyl chloride)
1,2-Dibromo-3-chloropropane (DBCP, Nemagon)
1,2-Dibromoethane (Ethylene dibromide, EDB)
Dibromomethane (Methylene dibromide) *
trans-1,4-Dichloro-2-butene ((Z)-1,4-Dichloro-2-butene) *
1,2-Dichlorobenzene (*o*-Dichlorobenzene)
1,3-Dichlorobenzene (*m*-Dichlorobenzene)
1,2-Dichloroethane (Ethylene dichloride)
trans-1,2-Dichloroethene ((E)-1,2-Dichlorothene)
Dichloromethane (Methylene chloride)
1,2-Dichloropropane (Propylene dichloride)
2,2-Dichloropropane *
1,3-Dichloropropane (Trimethylene dichloride) *
trans-1,3-Dichloropropene ((E)-1,3-Dichloropropene)
cis-1,3-Dichloropropene ((Z)-1,3-Dichloropropene)
1,1-Dichloropropene *
Diethyl ether (Ethyl ether) *
Ethenylbenzene (Styrene)
Ethyl methacrylate *

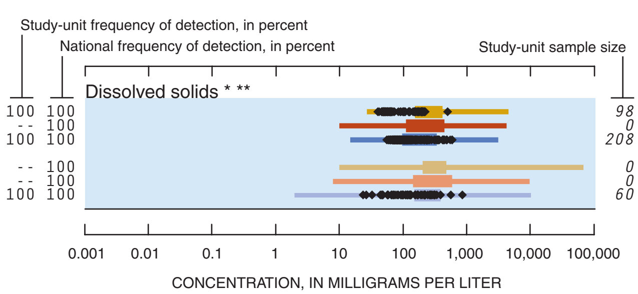
Ethyl *tert*-butyl ether (Ethyl-*t*-butyl ether (ETBE)) *
1-Ethyl-2-methylbenzene (2-Ethyltoluene) *
Hexachlorobutadiene
1,1,1,2,2,2-Hexachloroethane (Hexachloroethane)
2-Hexanone (Methyl butyl ketone (MBK)) *
p-Isopropyltoluene (*p*-Cymene) *
Methyl acrylonitrile *
Methyl-2-methacrylate (Methyl methacrylate) *
4-Methyl-2-pentanone (Methyl isobutyl ketone (MIBK)) *
Methyl-2-propenoate (Methyl acrylate) *
Naphthalene
2-Propenenitrile (Acrylonitrile)
n-Propylbenzene (Isocumene) *
1,1,2,2-Tetrachloroethane *
1,1,1,2-Tetrachloroethane
Tetrachloromethane (Carbon tetrachloride)
1,2,3,4-Tetramethylbenzene (Prehnitene) *
1,2,3,5-Tetramethylbenzene (Isodurene) *
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113) *
1,2,3-Trichlorobenzene *
1,1,2-Trichloroethane (Vinyl trichloride)
1,2,3-Trichloropropane (Allyl trichloride)
1,2,3-Trimethylbenzene (Hemimellitene) *
1,3,5-Trimethylbenzene (Mesitylene) *

Nutrients in water

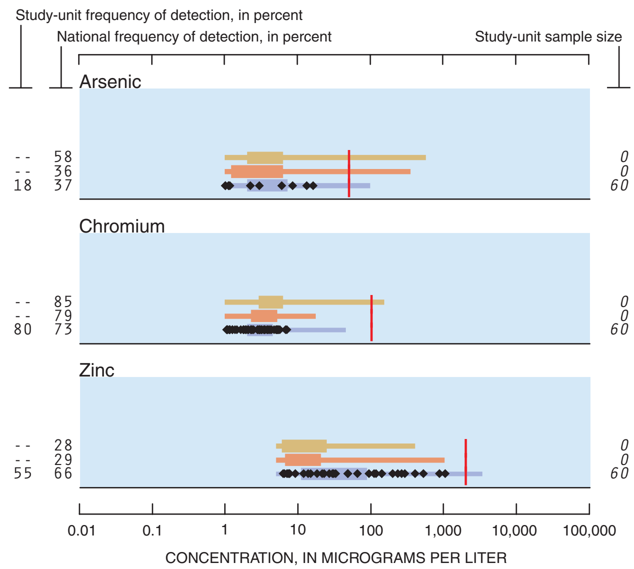


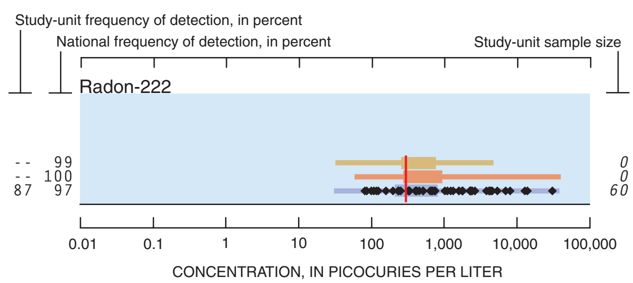
Nutrients not detected
Dissolved ammonia plus organic nitrogen as N * **

Dissolved solids in water



Trace elements in ground water





Other trace elements detected
Lead
Selenium
Uranium

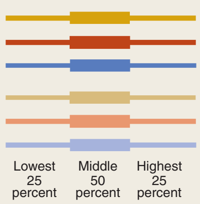
Trace elements not detected
Cadmium

CHEMICALS IN FISH TISSUE AND BED SEDIMENT

Concentrations and detection frequencies, Kanawha–New River Basin, 1996–98—Detection sensitivity varies among chemicals and, thus, frequencies are not directly comparable among chemicals. Study-unit frequencies of detection are based on small sample sizes; the applicable sample size is specified in each graph

- ◆ Detected concentration in Study Unit
- 66 38 Frequencies of detection, in percent. Detection frequencies were not censored at any common reporting limit. The left-hand column is the study-unit frequency and the right-hand column is the national frequency
- -- Not measured or sample size less than two
- 12 Study-unit sample size

National ranges of concentrations detected, by land use, in 36 NAWQA Study Units, 1991–98—Ranges include only samples in which a chemical was detected

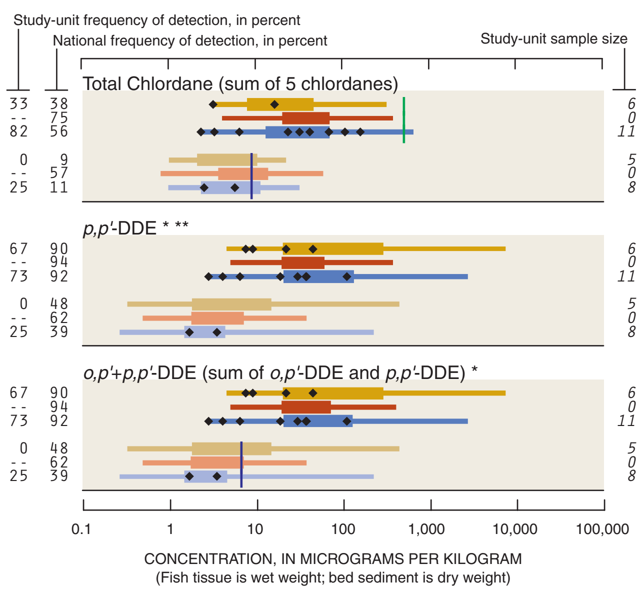


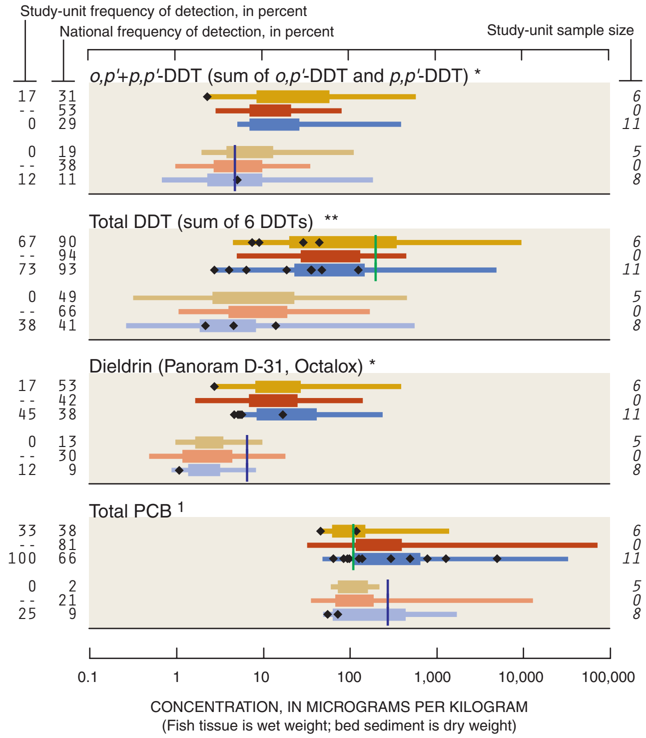
National benchmarks for fish tissue and bed sediment

National benchmarks include standards and guidelines related to criteria for protection of the health of fish-eating wildlife and aquatic organisms. Sources include the U.S. Environmental Protection Agency, other Federal and State agencies, and the Canadian Council of Ministers of the Environment

- | Protection of fish-eating wildlife (applies to fish tissue)
- | Protection of aquatic life (applies to bed sediment)
- * No benchmark for protection of fish-eating wildlife
- ** No benchmark for protection of aquatic life

Organochlorines in fish tissue (whole body) and bed sediment



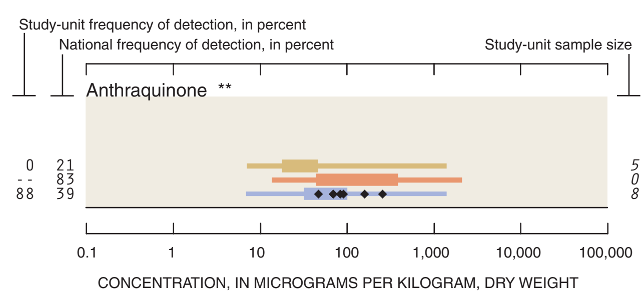


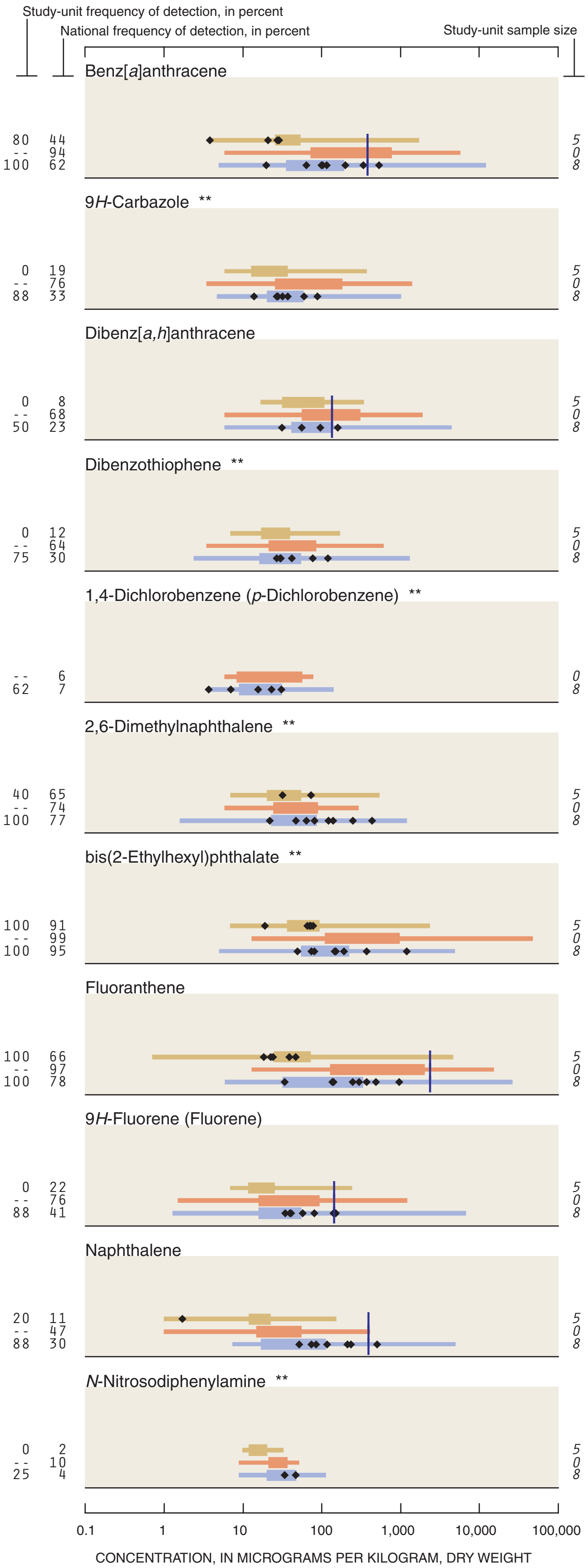
[1] The national detection frequencies for total PCB in sediment are biased low because about 30 percent of samples nationally had elevated detection levels compared to this Study Unit. See http://water.usgs.gov/ for additional information.

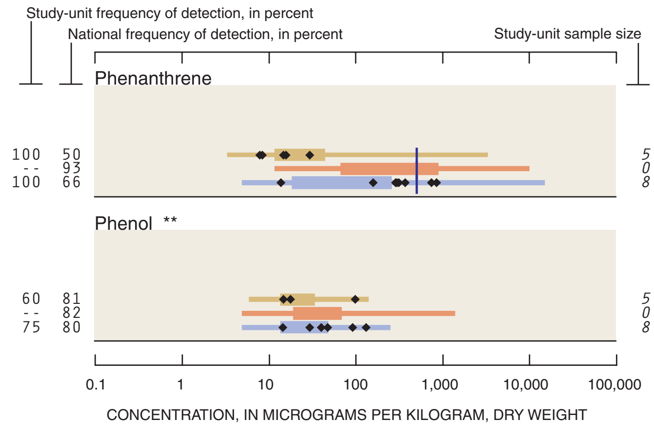
Other organochlorines detected
o,p'+*p,p'*-DDD (sum of *o,p'*-DDD and *p,p'*-DDD) *
Dieldrin+aldrin (sum of dieldrin and aldrin) **
Heptachlor epoxide (Heptachlor breakdown product) *
Heptachlor+heptachlor epoxide (sum of heptachlor and heptachlor epoxide) **

Organochlorines not detected
Chloroneb (Chloronebe, Demosan) * **
DCPA (Dacthal, chlorthal-dimethyl) * **
Endosulfan I (alpha-Endosulfan, Thiodan) * **
Endrin (Endrine)
gamma-HCH (Lindane, gamma-BHC, Gammexane) *
Total-HCH (sum of alpha-HCH, beta-HCH, gamma-HCH, and delta-HCH) **
Hexachlorobenzene (HCB) **
Isodrin (Isodrine, Compound 711) * **
p,p'-Methoxychlor (Marlate, methoxychlore) * **
o,p'-Methoxychlor * **
Mirex (Dechlorane) **
Pentachloroanisole (PCA) * **
cis-Permethrin (Ambush, Astro, Pounce) * **
trans-Permethrin (Ambush, Astro, Pounce) * **
Toxaphene (Camphechlor, Hercules 3956) * **

Semivolatile organic compounds (SVOCs) in bed sediment



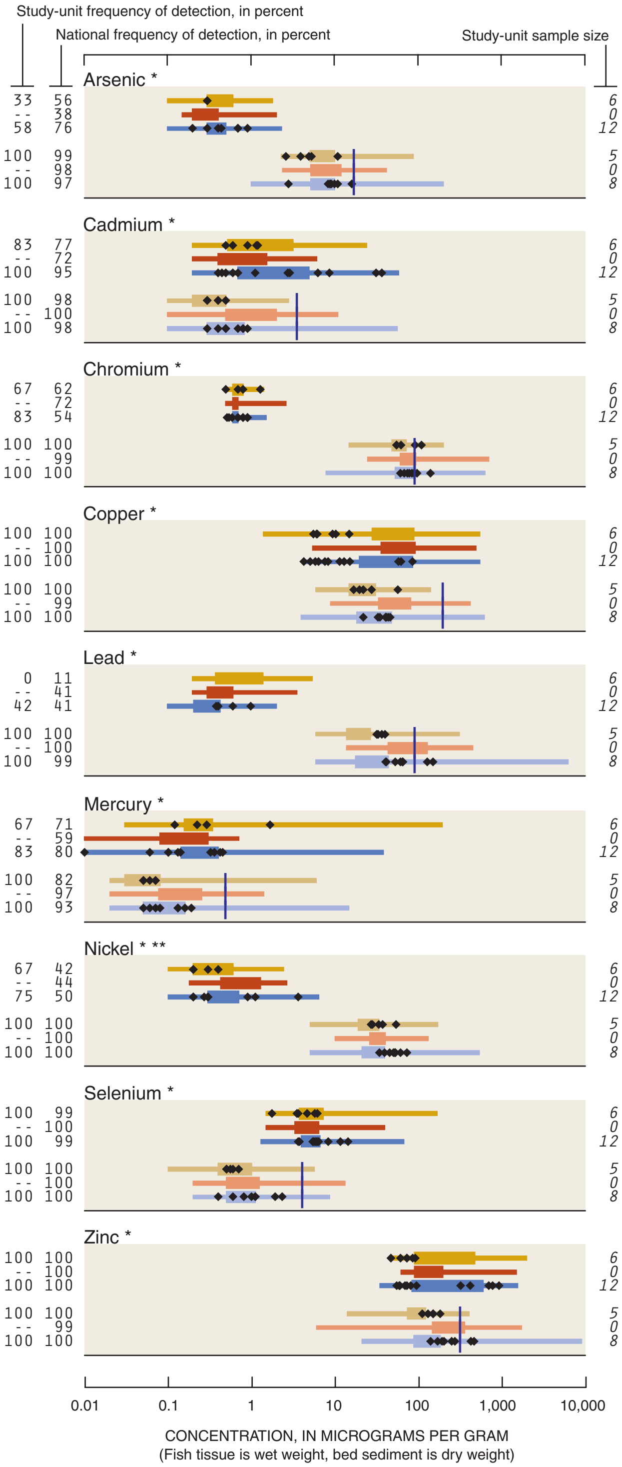




Other SVOCs detected
Acenaphthene
Acenaphthylene
Acridine **
C8-Alkylphenol **
Anthracene
Benzo[*a*]pyrene
Benzo[*b*]fluoranthene **
Benzo[*ghi*]perylene **
Benzo[*k*]fluoranthene **
Butylbenzylphthalate **
Chrysene
p-Cresol **
Di-*n*-butylphthalate **
1,2-Dichlorobenzene (*o*-Dichlorobenzene) **
Diethylphthalate **
1,2-Dimethylnaphthalene **
1,6-Dimethylnaphthalene **
3,5-Dimethylphenol **
Dimethylphthalate **
2,4-Dinitrotoluene **
Indeno[1,2,3-*cd*]pyrene **
Isoquinoline **
1-Methyl-9*H*-fluorene **
2-Methylanthracene **
4,5-Methylenephenanthrene **
1-Methylphenanthrene **
1-Methylpyrene **
Phenanthridine **
Pyrene
Quinoline **
1,2,4-Trichlorobenzene **
2,3,6-Trimethylnaphthalene **

SVOCs not detected
Azobenzene **
Benzo[*c*]cinnoline **
2,2-Biquinoline **
4-Bromophenyl-phenylether **
4-Chloro-3-methylphenol **
bis(2-Chloroethoxy)methane **
2-Chloronaphthalene **
2-Chlorophenol **
4-Chlorophenyl-phenylether **
Di-*n*-octylphthalate **
1,3-Dichlorobenzene (*m*-Dichlorobenzene) **
Isophorone **
Nitrobenzene **
N-Nitrosodi-*n*-propylamine **
Pentachloronitrobenzene **

Trace elements in fish tissue (livers) and bed sediment



BIOLOGICAL INDICATORS

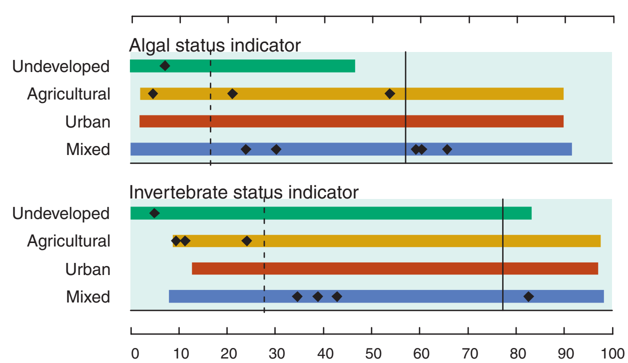
Higher national scores suggest habitat disturbance, water-quality degradation, or naturally harsh conditions. The status of algae, invertebrates (insects, worms, and clams), and fish provide a record of water-quality and stream conditions that water-chemistry indicators may not reveal. **Algal status** focuses on the changes in the percentage of certain algae in response to increasing siltation, and it often correlates with higher nutrient concentrations in some regions. **Invertebrate status** averages 11 metrics that summarize changes in richness, tolerance, trophic conditions, and dominance associated with water-quality degradation. **Fish status** sums the scores of four fish metrics (percent tolerant, omnivorous, non-native individuals, and percent individuals with external anomalies) that increase in association with water-quality degradation

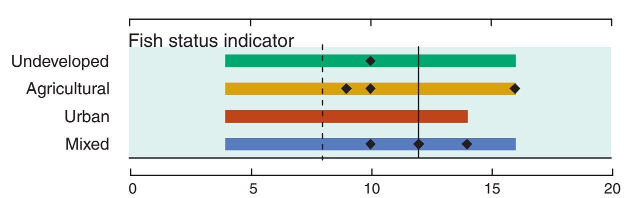
Biological indicator value, Kanawha–New River Basin, by land use, 1996–98

◆ Biological status assessed at a site

National ranges of biological indicators, in 16 NAWQA Study Units, 1994–98

- Streams in undeveloped areas
- Streams in agricultural areas
- Streams in urban areas
- Streams in mixed-land-use areas
- 75th percentile
- 25th percentile





A COORDINATED EFFORT

Coordination with agencies and organizations in the Kanawha-New River Basin was integral to the success of this water-quality assessment. We thank those who served as members of our liaison committee.

Federal Agencies
National Park Service
U.S. Army Corps of Engineers
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Office of Surface Mining
U.S. Department of Agriculture
  Agricultural Research Service
  Natural Resources Conservation Service
  Monongahela National Forest

State Agencies
North Carolina Division of Environmental Management
Virginia Department of Environmental Quality
Virginia Department of Game and Inland Fisheries
Virginia Department of Health
Virginia Division of Mineral Resources
Virginia Division of Soil and Water Conservation
West Virginia Bureau for Public Health
West Virginia Division of Environmental Protection
West Virginia Division of Natural Resources
West Virginia Geological and Economic Survey
West Virginia Soil Conservation Agency

Universities
Marshall University
Virginia Polytechnic Institute and State University
West Virginia University

Other public and private organizations
Cacapon Institute
Canaan Valley Institute
Greenbrier River Watershed Association
National Committee for the New River
New River Community Partners
Ohio River Valley Water Sanitation Commission
West Virginia American Water Company
West Virginia Citizens Action Group
West Virginia Coal Association
West Virginia Farm Bureau
West Virginia Highlands Conservancy
West Virginia Manufacturers Association
West Virginia Mining and Reclamation Association
West Virginia Rivers Coalition
West Virginia Rural Water Association

We gratefully acknowledge the cooperation of numerous property owners who provided access to sampling locations on their land. We also thank the following individuals for contributing data, knowledge, time, and expertise to this effort.

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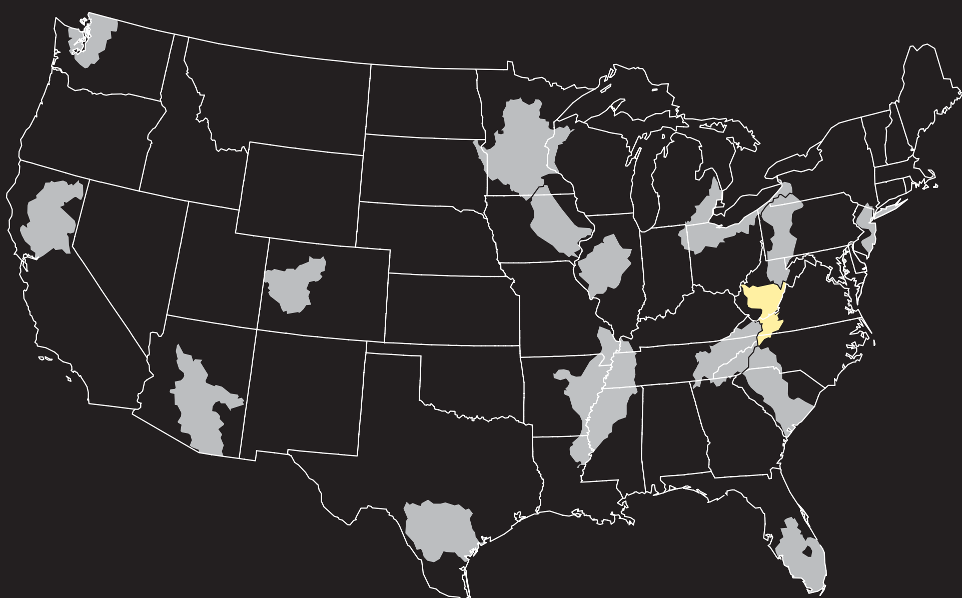
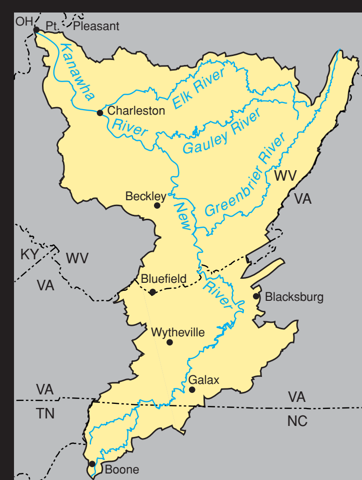
NAWQA

National Water-Quality Assessment (NAWQA) Program
Kanawha–New River Basin





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MOUNTAINTOP REMOVAL MINING/VALLEY FILL ENVIRONMENTAL IMPACT STATEMENT TECHNICAL STUDY

PROJECT REPORT FOR TERRESTRIAL STUDIES

March 2003

Terrestrial Plant (spring herbs, woody plants) Populations of Forested and Reclaimed Sites

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EXECUTIVE SUMMARY

The data presented in this report were collected in the spring and summer of 2000. They examine the pattern of revegetation of mountaintop removal and valley fill mining sites in southern West Virginia. The forests that are being removed by mountaintop removal and surface mining activities are located in the Mixed Mesophytic Forest Region. This region has very high biodiversity at the community level, and is among the most biologically rich temperate regions of the world (Figure 1. Hinkle et al. 1993). These forested mountaintops are predominantly being replaced by grasslands, although grasslands are not a naturally occurring habitat in this region (Figure 2. Hinkle et al. 1993). Blocks of young trees, some exotic, are often added to the final revegetation mix after grass establishment is successful. There is now great interest in developing and implementing mining practices that will have the least impact on future economic and ecosystem health.

Fifty-five transects on sites ranging in age from eight to twenty-six years since revegetation were visited in southern West Virginia by this investigation team. Plant species, sizes, and distribution were recorded across these sites for all woody species. Data from adjacent, unmined mature forests were also recorded. Invasion of native species onto reclaimed mined sites and valley fills was very low and restricted to the first several meters from the adjacent forest edge. Most of the plants found on mined sites were in the smallest (<1" diameter) size class, suggesting that the sites are stressful to plant growth and survival. Many of the species found in adjacent unmined forests are not present on the mined sites. Poor vegetation development with time was typical of the sites reclaimed after the 1977 SMCRA law. Diversity was significantly lower on the mined sites than in adjacent forests.

These data and other published studies support the conclusion that mining reclamation procedures limit the overall ecological health and plant invasion of the site. Plant invasion and success are dependent upon reclamation practices. Less soil compaction, smaller mining areas, healthy soil profiles, and native plant material all would support a healthier ecosystem return, although full premining biodiversity may be difficult to achieve. Sites that were reclaimed with pre-law protocols supported a richer flora than post-law sites, but this may be attributed to small scale, less compacted mining procedures. They also contained more native plants and represented all age classes unlike the post-law sites.

Herbaceous species were also studied on nineteen transects, in mature forests and on transects adjacent to mined sites. The loss of spring herbs on engineered sites was highly significant compared to forests away from mining activity. Information gathered from this aspect of the study shows that monitoring the forest herbs adjacent to mining activity is an additional useful indicator of environmental impact. The heavy compaction of the artificial slopes created during valley filling also contributes to these slow invasion rates. Additionally, the grassy vegetation mixes usually installed during revegetation are known to hinder the ability of the native plant species to establish. The poor invasion and growth of native vegetation across these study sites support the conclusion that these lands will take much longer than the natural time scale observed in old field succession to return to the pre-mining forest vegetation.

Objectives:

The objective of this study was to determine the patterns of terrestrial vegetation on areas affected by mountaintop removal mining and valley fills in the southern Appalachian region, and on adjacent, non-mined areas. Specific goals were to identify plant species present, determine the relative numbers of species present, record the size class distribution based on diameter at base or diameter at breast height of each species, and to document the pattern of vegetation from toe of slope to top of slope and from forested areas to mined areas. These data will enable investigators to understand the potential for re-establishment of native vegetation and document the actual change in vegetation since revegetation of the mined sites.

Importance of the objectives:

It is important to know the fate of the mined lands after reclamation, to determine the potential for re-establishment of surrounding native vegetation, and to see if a flora different from the vegetative mix installed upon reclamation can establish. The soils, seed pool, and local conditions on mined sites are quite different from the original conditions. It must be understood if mined areas will develop differently from the forested terrestrial communities surrounding the mined sites. These data are also needed to assess the quality of the habitat for animals of the region. If current reclamation methods are creating different habitat types, this must be known precisely, so that regulatory actions can be created to account for such changes.

METHODS:

Tree and shrub studies - site selection:

In order to assess the progress of invasion of woody species onto reclaimed mine lands, sites were selected that had a remnant forest adjacent to the mined area. A remnant forest is a forest that is directly bordering an active mining site or in this case, reclaimed sites. They are passively disturbed by mining activity through many ways including pollution, ground disturbance from blasting, hydrology changes and siltation, and increased edge area. These reclaimed areas were considered most relevant for this study because they included a nearby seed source for the mined area, therefore offering an opportunity for woody species to invade the open, disturbed land. Study of mined lands adjacent to mature forests, of course, maximizes the potential for invasion of species, and potentially weighs the data sets towards higher invasion rates. However, it is necessary to see invasion, and the intensive sampling of edge areas gives the investigator a higher potential for determining invasion rates.

Sites across the mining region of southern West Virginia were selected to represent a wide variety of ages, conditions, and treatments. The sites in this study were recommended by EPA, WVDEP, FWS, and mining officials and engineers who worked for the mining companies that participated in the study. Knowing that the goal of this study was to record re-establishment of woody vegetation on modern, mountain-top mined lands, mining officials (list of personnel can be provided by investigators) directed our team towards the richest sites available.

All of the recommended sites were studied during our survey, in standing with the policy to visit every site recommended by stakeholders. Data from all these sites are included in our tables and analyses, except for one of the first sites visited, a contour mine at Honey Branch, WV. This site had been planted with dense rows of non-native autumn olive and with alder trees in the past. To test field methodology, we counted and identified all woody stems at this site across a 10 x 175 meter transect, through the plantings, without recording stem size classes. We found that this method was at once too time consuming to allow a broad sampling of the entire West Virginia portion of the EIS study area (a requirement for this EIS) and not precise enough to understand the temporal pattern of revegetation. Linking size class to stem identification gives a clearer analysis of site fate. Consequently, at all sites visited and studied after this trial run, we took the time to record stem size class, and sampled only at 20m intervals along the transect. Because of the differences in sampling methodology, the Honey Branch data could not be statistically analyzed with the rest of the data set and are not included in the tables. The raw data from this site are on file and available along with all other data, and show a revegetation pattern quite similar to the fifty-five transects included in this report.

For all other sites, at each specific locale, transects were positioned in a standardized location and vegetative cover and density were similar. The total number of forest transects surveyed and reported is 25 and the total number of mined land transects is 30. Ten different mine properties were surveyed, with ages ranging from eight to twenty-six years since revegetation. Emphasis was on surveys of sites that were older, but reclaimed after the 1977 surface mining law (SMCRA) was put into effect. Changes in reclamation protocols necessitated by that law caused important differences in reclamation practice (Vories and Throgmorton, 1999). A complete list of study sites is in the Appendix (Table 1).

Tree and shrub studies – data collection:

The first aspect of this study involves twelve transects that were run vertically down slope from a mined land (i.e. valley fill, mountain-top removal area, backfill, or contour mine) into an adjacent, mature, remnant forest apparently unaffected by mining activity (Figure 3a). (Many of these forested sites were once logged and showed vestiges of former rough logging roads. Consequently, these forests have been modified by human activity and are not considered intact or pristine forests. However, all forested areas contained large, diverse canopy trees with well-developed stands and unexcavated soil.) The transect line was continuous from mined area to the adjacent remnant forest, or in some instances started in the remnant forest above the reclaimed site and ran down into the mined land.

It is important to note the structure and nature of the *valley fills*. Transects were arrayed from top of slope to toe of slope (toe of slope in this study was defined as the bottom of the hill/fill where the ground leveled off, and/or the stream bank was reached), and ran the entire length of the fill. Because of the triangular geometry of valley fills (Figures 3a and 3b), areas at the toe (base) of the slope were surrounded on two sides by remnant forests. They were much moister areas than the top of the fill, due to storm water run-off and ground water. Because the toe of slope is wetter, much narrower, and much closer to remnant forests (on both sides), we see an increase in stem density that is indicative of an "edge effect." Some of the valley fills had forest remnants at the top of the slope as well as at the bottom, therefore creating two zones of forest edges. Where this was the case, the top forest remnant was sampled and the bottom one was not.

There were an additional 43 transects studied where it was not possible to run continuous transects, as above. In these cases, the forest remnant transect was run perpendicular or adjacent to the mined area transect, as shown in Figure 3b.

Data were collected during the year 2000 growing season only. The presence of woody plants on these sites represents the reproductive performance of many years. The boundary, or edge, between forests and reclaimed mine land was recorded for each transect and is the "0" point on all data sets and graphs. The point-quarter sampling method was used to survey the woody plant community (Barbour, Burk, et al. 1999). This technique was used as it allowed the investigating team to cover the most ground, the most sites, and collect the most data points in the time frame given. There is a potential to underestimate rare species with this technique, as a census of all plants in an area is not done. However, a species effort curve performed on the data indicates that few, if any, rare species were missed given the large data set that covers thousands of individual plant records. Consequently, the field sampling technique is representative of the woody species on site.

At each sampling point, located at 20 meter intervals along the transect line, the area was divided into four quadrats. In each quadrat the distance was measured from the sample point on the transect line to the nearest woody plant and recorded for three different size classes, for a potential of twelve individuals per transect point. The size classes were defined as "small" (0-2.54cm), "medium" (2.54-7.62cm), and "large" (more than 7.62cm) based on diameter at base of stem. For each of these stems, the nearest neighbor's distance and species identification were recorded, as well as the distance to the nearest conspecific (individual of the same species). Trees that were obvious parts of an implemented planting program (determined by plantation spacing and diameter at breast height) were not included in the counts, as these did not naturally arrive on the sites and are not part of any invasion process. Any offspring produced by planted individuals were included in the data, however. We were not interested in survival of the planted trees, as all planted species we encountered are either forestry created hybrids or non-native and in fact illegal to plant in many states. Data were entered on computer databases for further study. Leaves and stems of questionable plants were collected and keyed out using herbarium specimens. Occasionally, specimens could not be keyed to species because they were barren of flowers or fruits; it was impossible, given the rapid time frame of the study, to return to each site at other seasonal times in the year 2000 to search for reproductive specimens.

Tree and shrub studies –data analysis:

Comparing the mined sites to the adjacent remnant forests is difficult at best. Mines are viewed by some as representatives of "primary successional soil/plant systems." Comparing them to the "native forest stands [as] largely secondary successional systems" is therefore like comparing apples and oranges. (W. Lee Daniels, personal communication). First, the mined lands are <u>not</u> primary successional landscapes. Primary succession is defined as "The development of an ecosystem in an area that has never had a living community..... Examples of areas in which a community has never lived before would be new lava or a rock from a volcano that makes a new island or a new landscape, or a sand bar that arises from shifting sands in the ocean" (University of North Carolina Wilmington). The question is not how the data were compared, but the task set before us was to document the invasion process from forest remnants to reclaimed land, to describe the vegetation and note patterns based on our knowledge and experience as restoration ecologists. We documented the successes and failures of natural recruitment onto these early successional landscapes, and analyzed our findings with statistics that allowed for such comparisons, which follow.

As previously mentioned, the objective of this terrestrial study was to determine the success of woody plant invasion onto the disturbed mining areas. The data were examined in several ways. Transects were categorized as one of six types: continuous forest (CF); remnant forest (RF); valley fill (VF); mountaintop removal area (MTR); backfill (BF); or contour mine (CM). Continuous forests are forests located away from mining activity and therefore not significantly impacted by mining activity, whereas remnant forests, as previously defined, are forests directly adjacent to and affected by mining activity. Remnant forests are typically smaller parcels than the continuous forests, but this is not a defining characteristic. Data were displayed within each of the six categories by the three size groupings of plants: small; medium; and large. The density of woody plants by size class was also determined. These densities were compared in order to evaluate the progress of the woody invasion. Species lists of forests and mined areas were developed and comparisons between native forests and mined lands were performed. Plant diversity was estimated using the Shannon-Weiner statistic, which includes measures of number of species and their relative abundances. For example, if you had two stands with the same number of plants and the same number of species, they can be distinguished from one another if one stand has these species in more or less equal proportions; a more diverse stand would have these species in more equal numbers.

Herb studies – site selection:

Nineteen forested sites, considered to be either "intact" forest (11) or "engineered" forest (8), were chosen to evaluate the herb community, adjacent to the EPA aquatic biology team's locations. The terms "intact" and "engineered" forests comply with EPA terminology and are equated to "continuous" and "remnant", respectively, as described in the paragraph previously. Sections of watersheds that had been mined (the engineered forest) and areas that were distant from mining activity (the intact forest) were selected. Sites are listed in the Appendix (Table 2). This protocol allows comparison and correlation of herb data with the aquatic study, for a more complete understanding of these sites.

Herb studies – data collection:

The study team visited all sites during April and May 2000, to sample the spring herbaceous vegetation. Early season sampling of the herb flora was necessary, as many spring herbs often complete their life history before the summer months, then persist underground until the following year (Schemske, et al., 1978; Bierzychudek, 1982). Transects were sampled every 10 meters, starting at the base of the slope, up hill for an additional 50 meters. It was determined by the investigating team that the herb cover significantly diminished around 40 or 50 meters from base of slope, and data from a broader geographical range could be collected if this was a decided end point. At each sample location, a 5x1m plot across the face of the slope was censused for all herbs. Species identity and stem count for each species were recorded for each 5x1m plot. Samples of species were collected for herbarium records and identification verification.

Herb studies – data analysis:

Data were summarized to determine relative distribution and number of species on undisturbed forest slopes compared to forest slopes adjacent to disturbed areas (i.e. mines and wide road cuts). These data were entered in a database for statistical analyses to determine vegetation distribution patterns. Shannon-Weiner Index of Diversity was performed to determine diversity values for both forest types using mean number of stems counted and mean number of species present in both forest types.

RESULTS:

TREE AND SHRUB STUDIES:

Presence of trees and shrubs on the study sites:

The 99 species listed in Table 3 were found collectively on the 25 forest transects and 30 mined transects. Table 4 shows the differences in species composition across these two types, ranked from most to least commonly present. The species did not have to be abundant at a particular site to be included, merely present on the site (i.e. whether the species has one or one thousand individuals, it is recorded as "present"). These numbers do not include data that were collected from contour mine sites or their associated remnant forests, which have been treated and reported separately, so the sample size here is 23 forest transects and 25 mined transects. Most of the species found in the majority of forest transects were found on only a few mine transects, with the exception of *Acer rubrum*, *Liriodendron tulipifera*, and *Rubus* sp., which are regularly found as small plants in disturbed areas. There are twenty species occurring on the mined lands that are not found in the forested lands and thirty forest species not found on the mined lands. Of the twenty unique mine species, many of these are typical early successional species *(Acer rubrum, Liriodendron tulipifera, Rubus* sp.*)* and many others (*Pinus* sp. and *Robinia pseudoacacia*) are offspring of the trees planted as part of reclamation efforts. Overall, there are ten more species found in the forest than on the reclaimed mined lands. This is not unusual given the very different stages of succession that these lands are in.

The data from Table 4 can also be summarized across sites by richness, defined as the number of species found regardless of abundance. Figure 4 shows that the forested category always contains more species than the sites in the reclaimed mine category, when listed from most to least rich site (i.e., the woody species are not growing in as much variety on the mined sites as in the forests.). In other words, the forests have higher plant species richness and more plant biodiversity than the mine sites (Figure 4).

Species-presence data can also be arrayed by individual species, in addition to the site values shown in Table 4 and Figure 4. Figures 5a and 5b illustrate the number and percent of transects studied where each species in the data set was found. Forested sites have a higher percent of transects represented for the majority of species. These data indicate that woody species occur across the entire forest transect, they are not just sequestered in a few unusually rich transects that happened to be included in the surveys.

There is special interest in the major tree species of the forest, as these are of possible commercial interest. Figures 6a and 6b display six of the most common hardwood tree species found by absolute number and percent of all woody stems found (total of 4,140 stems in the data sets, including all size classes). These trees are always more abundant as a proportion of stems on the forested sites. Five of the six are more common by absolute number on the forested sites; only *Acer rubrum* has more individuals on the mined sites, as many seedlings of this species were present. Further observations should be made on the reclaimed mine lands to see how well these economically viable species establish and grow.

Woody species found can also be displayed according to mine type (Table 5), to more clearly see if there are special determinants associated with species presence. Again, these numbers are based simply on being present at all, not abundance. Remnant forests have the most species, and mountaintop removal sites (MTR) have the fewest, when grouped in this way. However, only four MTR sites were examined as opposed to twenty remnant forest sites. If one examines the average number of species by site (see site table in appendix to see number of species per site), MTR's have 6.25 and remnant forests have 17.7 species on average. Table 5 also illustrates that some species (for example *Acer rubrum* and *Liriodendron tulipifera*) are more generalist (i.e. are found on all the site types). Others were found only on mined areas (*Lespedeza bicolor*) or only in forests (*Acer pensylvanicum, Lindera benzoin*). Once again, these species differences can be greatly attributed to varying successional stages.

The distribution of species can also be considered in terms of how abundant, or how frequently, the species appeared on the site (Table 6). Most species found in great number in the forests are not found in similar abundance on the mined sites. At the same time, common woody species on the mined sites, typical of earlier successional stages, are not found as abundantly in the forests. This is simply a matter of succession. The reclaimed mine lands are in a much earlier stage of succession or development than the forests, and one would expect to find different species compositions as a result of the various stages.

The forest community is comprised of a greater number of species. It is also a more diverse community than the mine land communities. More uncommon species occur in the forest and there is less dominance by a few common species. That is, the mine sites have a few dominant species making up most of their communities and few rare species present. Figures 7a and 7b illustrate the number of woody plants found during the point quarter sampling. The mine plot in Figure 7b is based on percentages, which allows a simpler comparison, as sampling effort was unequal between mine and forestlands. The mine species distribution starts quite low on the y-axis because there were many points, about 1600, where woody stems were not present at all (this very high point is not plotted on this graphic). Absence (not falling within sampling range) of a woody plant was rarely experienced on any of the forest sample points. Having more species that occur more evenly or frequently (i.e. not having a population dominated by only a few species) creates a more diverse environment. For many of the species found, the percent occurrence is high in forests. Having all the species occur only once or twice, such as on the mine lands, and being dominated by only a few species, creates a less diverse community.

There is growing concern over alien and invasive plants across all landscape types throughout the United States. This survey encountered very few invasive or alien plant species on mined-lands or in the forests (Tables 3, 7a and 7b note non-native species). Most of the non-native individuals observed were those that were planted as part of a reclamation effort (i.e. Autumn olive is both exotic and very invasive and every mine visited was using it for reclamation). There were several other exotic species that were observed, including Tree-of-heaven, Japanese honeysuckle, Princess-tree, and Multiflora rose that arrived on site naturally. Japanese Knotweed was also observed along the stream banks in developed areas.

Distribution of trees and shrubs across the study transects:

To spatially study the process of invasion, data were displayed across the x axis in figures 8-12, where "0" represents the edge, the sharp boundary between forest and reclaimed mine area. In these graphics, all alien species were removed from the data sets, as the interest in this study is the reappearance of the native West Virginia plant community. These data (in Figures 8-12) are from the twelve continuous transects described earlier (page 1). There are three Mountain-top Removal (MTR), three Valley Fill (VF), three Backfill (BF), and three Contour Mine (CM) sites, all with paired forest remnants. The following figures graph the mean stem densities per $25m^2$.

Figures 8a, 8b, and 8c illustrate the stem densities calculated for the small, medium, and large size-classes, for woody individuals on nine continuous mine to forest transects (contour mines not included in total density graphs). A "continuous transect" (Figure 3a) is a location where only one line was run, going from mine land directly into the remnant forest, or vice versa. Figure 8a shows that the small individuals (2.54cm and smaller diameter at base) are not regenerating on the mined lands as abundantly as they do in the forest. Figure 8b shows that establishment of the medium size class individuals (2.54-7.62cm diameter at base) is not as high on the mined lands as it is in the forests. (Figure 8c) Large individuals (7.62cm diameter at base) are barely present on the mining areas. There is little to no growth into this size class. This is not an unreasonable size class to reach given the age of these mines (range of 8 to 26 years old since revegetation).

The six most common forest tree species have the following age and size projections under optimum soil conditions: *Acer rubrum* can reproduce at an age as early as 4 years, with a size of 5-20cm diameter at breast height (DBH). *Quercus rubra* is 25 years at first reproduction with 60-90cm DBH. *Liriodendron tulipifera* is 15-20 years at first reproduction, with DBH of 17-25cm. *Acer saccharum* will reproduce as early as 22 years, with DBH equal to 20cm. *Fagus grandifolia* reaches substantial seed production at age 40 or with a DBH of 6cm. *Magnolia acuminata* starts reproducing at age 30, optimum at age 50, with DBH unreported (Burns and Honkala, 1990, for these data). These data should be carefully interpreted, as they are in optimum conditions, conditions that are not experienced on reclaimed mine lands. However, there are no age estimates published for such lands, with similar aspect, elevation, topography, etc. that we are aware of to compare our data to. The age and size estimates given above are at breast height, roughly 1.22m (4') high, for the average adult. The size classes used in this report were determined at the *base* of the plants, as most of the individuals were no taller than

61cm. The reclamation age of many of the mine sites is nearing or has reached the reproductive age for several of these trees, but this study's data indicates that trees in mine spoils have not approached the correlated sizes.

The woody data from reclaimed mine transects can also be divided into the four mining categories: Mountain-top Removal (MTR), Valley Fill (VF), Backfills (BF), and Contour Mine (CM). Figures 9a, 9b, and 9c illustrate the stem densities calculated for woody individuals in all three size-classes, on three MTR sites and the paired remnant forest transects. Figure 9a shows that the small individuals (2.54cm and smaller diameter at base) are not regenerating on the mine lands as they do in the forest, which is expected given the vast differences in soils. Of the three MTR's surveyed, one was eight years old since revegetation and the other two were both 17 years since revegetation. It is expected to see small size-class individuals well before 17 years is reached. The medium individuals (2.54-7.62cm diameter at base) (Figure 9b) are not present on these mined lands, and there are only a few large individuals (7.62cm diameter at base) present on the surveyed, reclaimed mine lands (Figure 9c).

Figures 10a, 10b, and 10c illustrate the stem densities calculated for woody individuals in all three size-classes on three Valley Fill sites, that accompany MTR sites, and the paired remnant forest transects. The remnant forests of two of these transects were located above the fill (Colony Bay: Cazy fill; Hobet Mine: Bragg Fork fill) and the other was located at the bottom of the fill (Leckie Smokeless: Briery Knob). Due to the triangular geometry of Valley Fills (Figure 3a), which (a) allows closer proximity to forest edge, and (b) provides a moisture gradient created by the drainage ravines at the toe of the slope, there was an increase in stem densities with decreasing elevation in the Valley Fill sites. This has apparently increased the presence of the small size-class plants in this mining area. However, the data for the medium and large size classes shows a decrease in this trend over time. Valley fills remain stressful sites for these seedlings, and slow growth or lack of survival could underlie these low data points. As these sites are ages 16, 21, and 25 years, a higher representation in all three sizes would be expected during successional change, even without optimal soil conditions.

Figures 11a, 11b, and 11c illustrate the mean stem densities calculated for woody individuals in all three size-classes on three Backfill sites and the paired remnant forest transects. One Backfill is 14 and the other two are 16 years old since revegetation. Figure 11a shows that the small size-class individuals are regenerating along the forest edge as would be expected, but taper off rapidly beyond 60 meters and are not found further from the edge. An edge effect can also be observed in the medium size-class (Figure 11b) in the first 20 meters that quickly fades until there are no medium individuals found beyond that point in great number. Few large size-class individuals were found on the mined sites (Figure 11c).

Figures 12a, 12b, and 12c illustrate the stem densities calculated for woody individuals in all three size-classes, on three Contour Mine sites and their paired remnant forest transects. All three of these sites are 12 years since revegetation. The contour mines that our investigators visited were much shorter in length than the other mine lands and were typically less compacted upon completion than flat areas, because of less grading activity (Vories and Throgmorton, 1999). Bonferroni T tests (Proc GLM in SAS/STAT version 6.12; SAS 1990) were run on the mean densities of the four mine types, by size class. The Contour Mines' plant densities in the small and medium size classes were significantly greater than all three other mine types (p_{small} =0.0011 and p_{medium} =0.0004) (Figure 13). Because all four mine types included in this study had so few large individuals, there was no significant difference among any of the mine treatments.

Regeneration of the small size-class individuals on the CMs illustrates the edge effect of a forest (Figure 12a). The CM's trend of regeneration falls abruptly after 10 meters, and suggests that few woody stems would be present beyond 50 meters (the local limit of this site). Figure 12b shows a pattern similar to Figure 12a, the smaller individuals are surviving into the next size class. No large individuals occurred within our sampling efforts on these CMs (Figure 12c). However, it has only been 12 years since revegetation at these sites and not many tree species are expected in this size class from seed this quickly (see maturation information in previous text).

Finally, one transect studied represents a unique site where it is possible to compare three types of land engineering, all at the same age, to determine what woody plants have naturally recruited into the site. This site was at Peerless Eagle Mine, and its age is estimated between 12 and 17 years. The top third is mountaintop removal, the middle third is a clear-cut forest remnant (apparently cut in preparation for the fill, but never filled to that height, and has since revegetated), and the bottom third is valley fill (Figure 14a). Consequently, the soil in the clear-cut area was only minimally disturbed; soil was removed or covered in the other areas. Figure 14b illustrates the lack of plant recruitment into the two engineered areas. During the same time, the central clear-cut area has fully revegetated, probably due to stump sprouts and germination from the undisturbed seed bank (Figure 14a). Soil quality is dramatically drawn into attention at this site. In the same amount of time, with the same external forces impacting the area, there is a remarkable lack of vegetation on the engineered sites.

Additional perspectives on trees and shrubs:

Once again, comparing these data between reclaimed lands and forests is difficult, in that we do not have a controlled environment or experiment. However, we must analyze the data to the best of our abilities and within the limits of statistical powers.

The Shannon-Weiner Index (H) is a measurement of community diversity, a function of both species number and relative abundance commonly used in vegetation analysis (Barbour, et al., 1999). For small, medium and large plant size classes, the diversity index is significantly higher (paired t test, df = 8, p_{small} = 0.0191, p_{medium} = 0.0082, p_{large} = 0.0033) on the forested parts of the transects (Figure 15), indicating greater species diversity than on the reclaimed mine lands.

Finally, figures 16a, 16b, and 16c compare mine age (since revegetation) and average total plant density on each transect site. Data from all remnant forest transects are shown as a mean of values, with standard deviation. These are displayed across the x-axis to allow a visual comparison with all of the values from the mine lands. However, this *does not represent* in any way the actual age of the forested sites; this acts as an approximate asymptote to which developing forests in this region might attain. The data for the forest were added to give a visual cue of where the average forest density is for each size class. Figures 16a, 16b, and 16c illustrate that mine age since revegetation does not positively correlate with increasing stem density. If the densities were increasing over time, one would see a positive regression line for the mines. However, for all three size classes there is no linear relationship, indicating no increase in number of individuals over time.

The last three data points along the x-axis (reclamation ages 23, 25, 26) of figures 16a-c are important to note. The two older mines were revegetated prior to the 1977 SMCRA laws, while the third was reclaimed just two years later, in 1979. The two older sites have revegetated much more quickly than the third site and all other sites visited. The medium and large size-class individuals were just within the remnant forest density mean (or very near the lower end of the range) at these two sites. What happened in two years to create such a change in reinvasion potential? Possible answers are scale of mining and reclamation practice (see Conclusions and Executive Summary).

General Conclusions for Trees and Shrubs:

There is a low number of species and an extremely low number of stems of woody plants on all mine types in this study compared to forests. The few native plants that do invade the mining areas are very close to the edge of the forest and are heavily concentrated in the smallest size class (less than 2.54cm diameter at base). The absence of significant numbers of stems larger than 2.54cm suggests that these are stressful sites, where very slow growth or high death rates for small plants are typical conditions. These are very low invasion rates compared to many sites adjacent to mature forests that do not have mining as a land use. As has been noted in many recent studies (e.g. Vories and Throgmorton, 1999), the combination of poor substrate quality and interference by inappropriate grass cover restricts the ability of native communities to return to these extensive land areas. Stands that have regenerated on pre-SMCRA sites often have diverse, productive forests (Rodrique and Burger, 2000), but newer protocols challenge this level of stand development, as is illustrated by these data.

A 1999 Greenlands article by Skousen et al. evaluated tree growth on surface mine lands in southern West Virginia. This study examined only three sites, two of which were pre-SMRCA law, and the third was reclaimed in 1980. Our team included all three of these sites in this study of 54 sites. Skousen's results clearly support our findings in that post-law sites are not regenerating as quickly as they could due to "[herb species suppressing woody seedling establishment], soil compaction and shallow soil depth." Similarly, in the pre-law sites that were not seeded with an herbaceous cover plant succession is rapid (Skousen 1999).

An in-press article by Holl (2002) shows the potential for reinvasion and recovery on reclaimed surface mined lands. It is extremely important to note that, like the Skousen article, her study was comprised of pre-law sites dating back to 1962 reclamations. She does not report how many of the 15 sites were post-law (post 1977), but her three age classes for the mines are 1962-1967, 1972-1977, and 1980-1987. Also, the mines in that report are small ¼ hectare parcels, not comparable to the large mountaintop removal areas subject to this study. The Holl study sites, only 62.5 x 40m in size, examined areas very close to seed sources, within "5-50 m from unmined forests." It becomes obvious that invasion is possible for many species if the landscape setting is different from current large-scale practice. We have yet to see evidence that the original community has or will return to these seriously degraded landscapes.

Recently, a new series of West Virginia State regulations was passed to detail better procedures for re-establishing forest lands on AOC mine sites. These regulations include detailed requirements in soil, cover, and landscape requirements to begin getting productive habitats returning to the land. These new active regulations could be the starting point to address the poor stand development seen on the sites recorded in this study. However, full return of the rich biodiversity of the historical forests of the region would require more intervention than the addition of several dominant species, as is required in the new West Virginia regulations.

Attempts to encourage woody establishment are being made by some industry participants. One of the current practices is to plant rows or blocks of a tree species (Autumn olive, Black locust, Black alder, pine) in an effort to create corridors – areas that seed dispersers (birds, mammals) might find inviting for perching, foraging, and protection, which then introduces seed into the area. Our study found that blocks of olives and pines had little to no plants establishing underneath them. These trees were usually planted very close together and both species tend to grow dense and bush-like. Seed was either excluded from the area or could not establish due to poorer soil quality or not enough light and rain penetration. The alder and locust blocks had more success. These trees grow much straighter and do not shade out seed-rain, light, or other resources as much as the other two species. Other attempts have been made as well, like experimenting with different crop trees.

HERB STUDIES:

Presence of herbs on the study sites:

The herb communities on the forested sites were generally dense and species-rich, as is typical of this region (Hinkle et al., 1993). Eighty-five herbaceous species have been identified (Table 7a), and more were found on site, which required flowering structures for complete species identification. The presence and composition of the forest herb stratum is critical for forest health, as these herbs maintain soil structure and add nutrients, and offer habitat and nutrients to many animal species.

Three of the nineteen transects were on valley fills, the rest in forests. Presence-absence of the woodland herbs was recorded at these three valley fill sites, so these data are analyzed separately from the remaining data, which follow. Woodland herbs were not expected to be observed in open, sunny fields, as most of the herbs on Table 7a require the shade and moisture of the forest floor. The species that were recorded on the mine sites are on Table 7b.

Of the remaining sixteen sites, eleven were in mature intact forests and five were on lands directly adjacent to mining activities, such as the mine itself, a railroad, or a busy vehicular haul road. These are the "engineered" forests. Table 8 lists herbaceous species found on study sites, ranked from most to least present. The engineered forest sites are contrasted with the intact forest sites to determine the effects of mining activity on adjacent forest herbs. There might not be direct physical destruction of these adjacent forest remnants, but the disturbance caused by high activity levels (i.e. mining equipment, blasting, fumes and exhaust from train engines and hauling vehicles), as well as sun shafts cutting through to the forest floor from adjacent human-dominated areas, may disrupt the forest community starting with the herbaceous stratum. Seventeen fewer species are found in engineered forests than on intact forested sites.

In analyzing species distribution on the slopes, intact sites have more species at any point than engineered sites (Figure 17a). This can be seen with a two-way analysis of variance (ANOVA) (Proc GLM in SAS/STAT version 6.12; SAS 1990) to test for the effects of treatment type, distance from toe of slope, and the interaction of treatment and distance on mean number of species. Significant results were found for treatment type and distance from toe of slope on the species mean (both had a p value = 0.0001), indicating that both the distance up the hill and the type of site affected the number of species. There was no significant interaction between environment and distance.

The herb stratum in the intact sites also contained more stems in study areas than in the engineered sites along the entire slope (Figure 17b). A two-way ANOVA was performed, testing treatment and distance on mean number of herb stems (treatment p = 0.0016 and distance p = 0.125). Treatment type was found to be significant for number of plants found. There was no significant interaction found for distance from toe of slope on number of stems. There was no significant effect of treatment and distance collectively on number of herb stems counted.

The diversity of the herb stratum follows a similar pattern as described above. Figure 17c shows that the engineered sites had less diversity than the intact sites at all but one point along the slope. ANOVAs show a significant value (p = 0.003) for treatment type, and a marginally significant result (p = .0989), at a lower level, for distance on diversity. Once again, there was no significant relation between treatment and distance.

Tables 9a and 9b record the herbaceous species found at study sites, ranked from most to least abundant (number of stems counted) in engineered and intact sites and by percent abundance, respectively. (The two tables record absolute number and percent of stems on these sites.) Several of the species, which are found most abundantly on the intact forest sites, were not present, or were present in very low numbers, on the disturbed engineered sites. This indicates that human activity is affecting the forest ecosystem and changing the community composition. Four of the top ten intact forest herbs are in the top ten of the engineered sites, however, three of the top ten were not present at all on the engineered sites. This might indicate that although some of the heartier species are persisting, some of the more sensitive species are disappearing.

Table 10 records herbaceous species found, ranked by abundance (number of stems counted) in engineered and intact sites. In this table, values have been standardized by multiplying engineered numbers by 11/5 to even out differences in the number of sites sampled. By equalizing the numbers, one can see the abundance of the species from a level starting point. (The total number of stems for the engineered and intact forests is 3978 and 8817 respectively.) The totals indicate, even when the differing number of sites is compensated for, that the density of herbaceous stems at the engineered sites was less than half that of the intact forest sites.

General Conclusions for Herbs:

When mine disturbance is adjacent to a forest (engineered forest), we found the herb community, important for nutrient status and wildlife values, to be much less dense and species-rich. Part of the reason for the difference in spring herb abundance and diversity can be attributed to mining activity. Mining activity (i.e. filling and contour mining) often results in covering up the toe of the slope, eliminating the most diverse and rich community habitats. In our study, the engineered sites we visited *may have been* the higher slope regions depicted in Figure 18. Therefore, the habitat may have been drier and less diverse than the intact forest sites due to the fact that it was the naturally drier, higher slope community. Also, because the engineered sites suffer more intense and frequent disturbance, the quantity of light penetrating the canopy may be increased. This increase in light energy reaching the ground can dry out the soil and make conditions less favorable for the spring herb population. These herbs rarely invade mining lands on the areas studied, so data sets used for woody plants did not include forest herbs because they were seldom, if ever, observed. (Dispersal limits and the need for shady, moist microhabitat are obvious limits to regeneration.) A return to full forest biodiversity of plants is apparently even more challenged on mining areas when herb species are added to a concern.

CLOSING STATEMENT:

OSM reviewers pointed out that the unstated goal in mine reclamation in the Appalachians is to render the land green and stable. Traditionally, attempts are not made to reclaim the ecology or even the land use capability required by law. This report addresses what was accomplished, not what could be. What we see is only what is politically feasible, not technologically possible.

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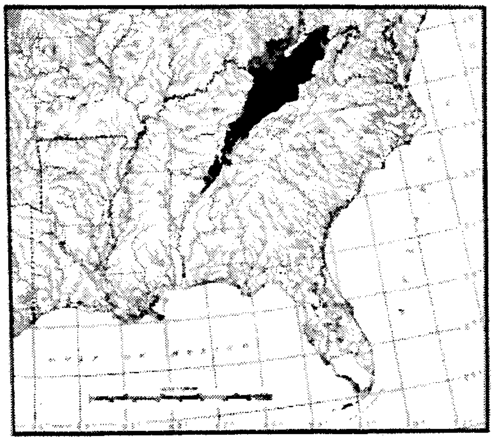


Figure 1. The blackened area illustrates the Mixed Mesophytic Forest Region of the southeastern United States. Taken from Hinkle et. al in Biodiversity of the southeastern United States, upland terrestrial communities.

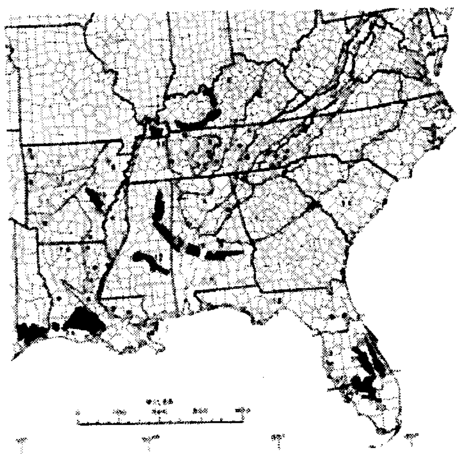


Figure 2. The naturally occurring grasslands of the southeastern United States. Taken from Hinkle et. al in Biodiversity of the southeastern United States, upland terrestrial communities.

Figure 3a. Diagram of valley fill geometry. Arrows indicate relative location and direction of transect lines on the valley fill and into the adjacent forest remnant. Darker line indicates how the 12 *continuous* transects were run from mined land to remnant forest.

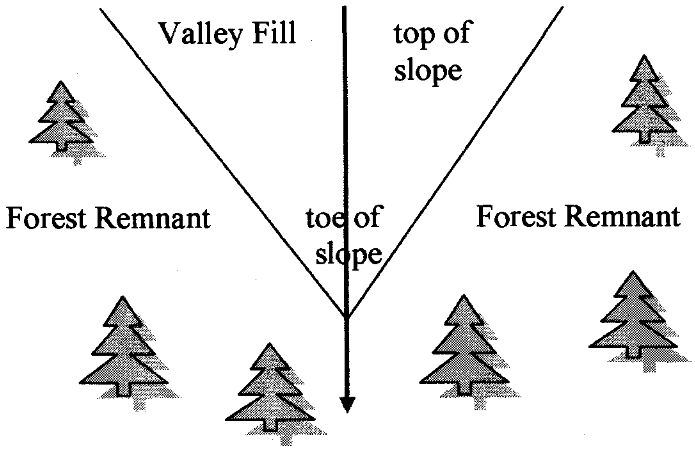


Figure 3b. Diagram of valley fill geometry when continuous line could not be run. Arrows indicate relative location and direction of transect lines on the valley fill and into the adjacent forest remnant. Darker lines indicates how the mined transect and forest transect were run. Only one forest transect was run, either on the left or the right, not both.

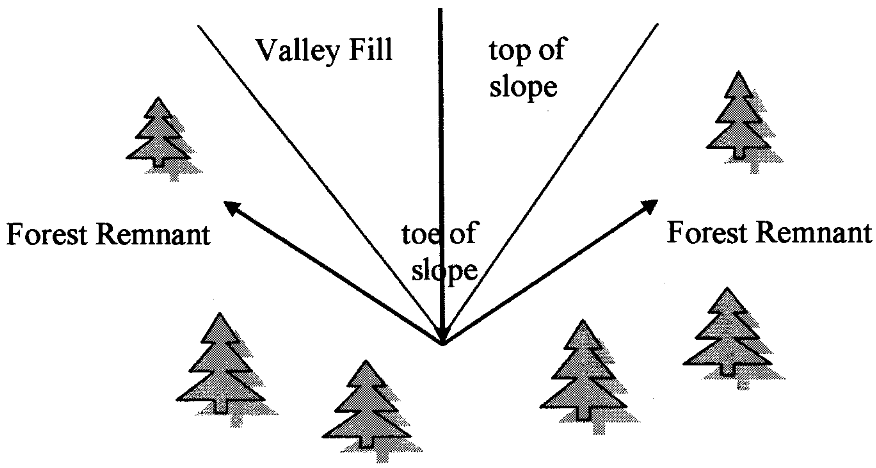
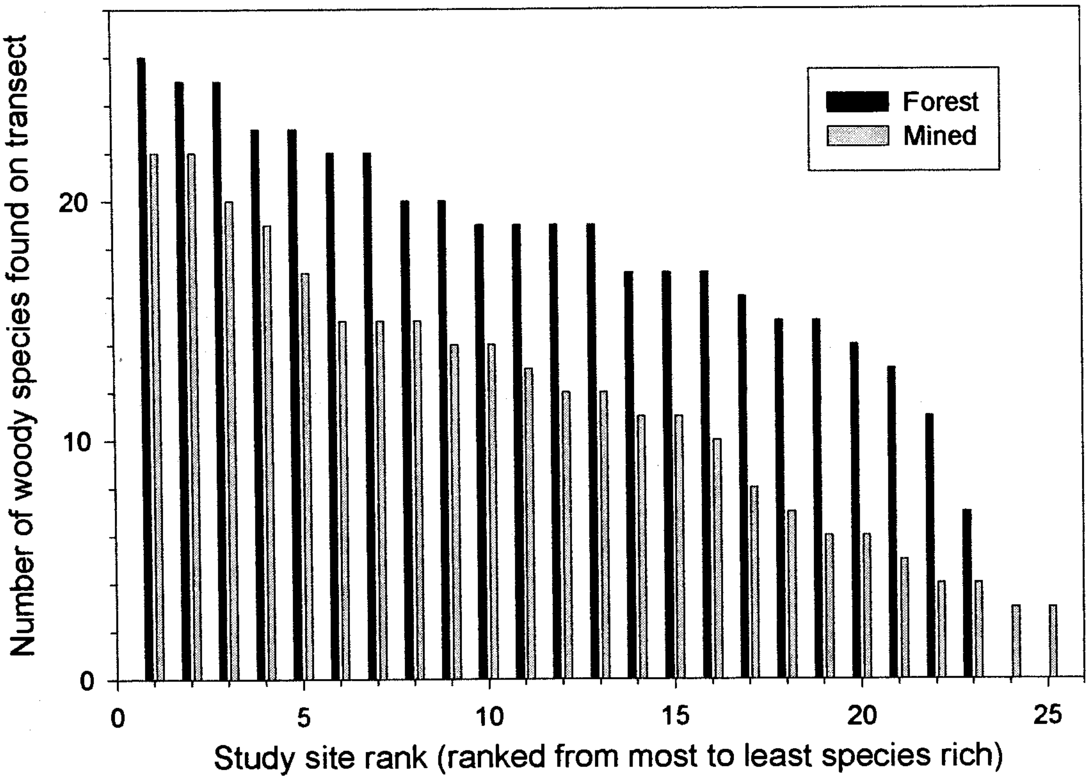


Figure 4. Woody species richness on all study sites. Sites are ranked not in pairs, but in decreasing species richness. Contour mine data not included.



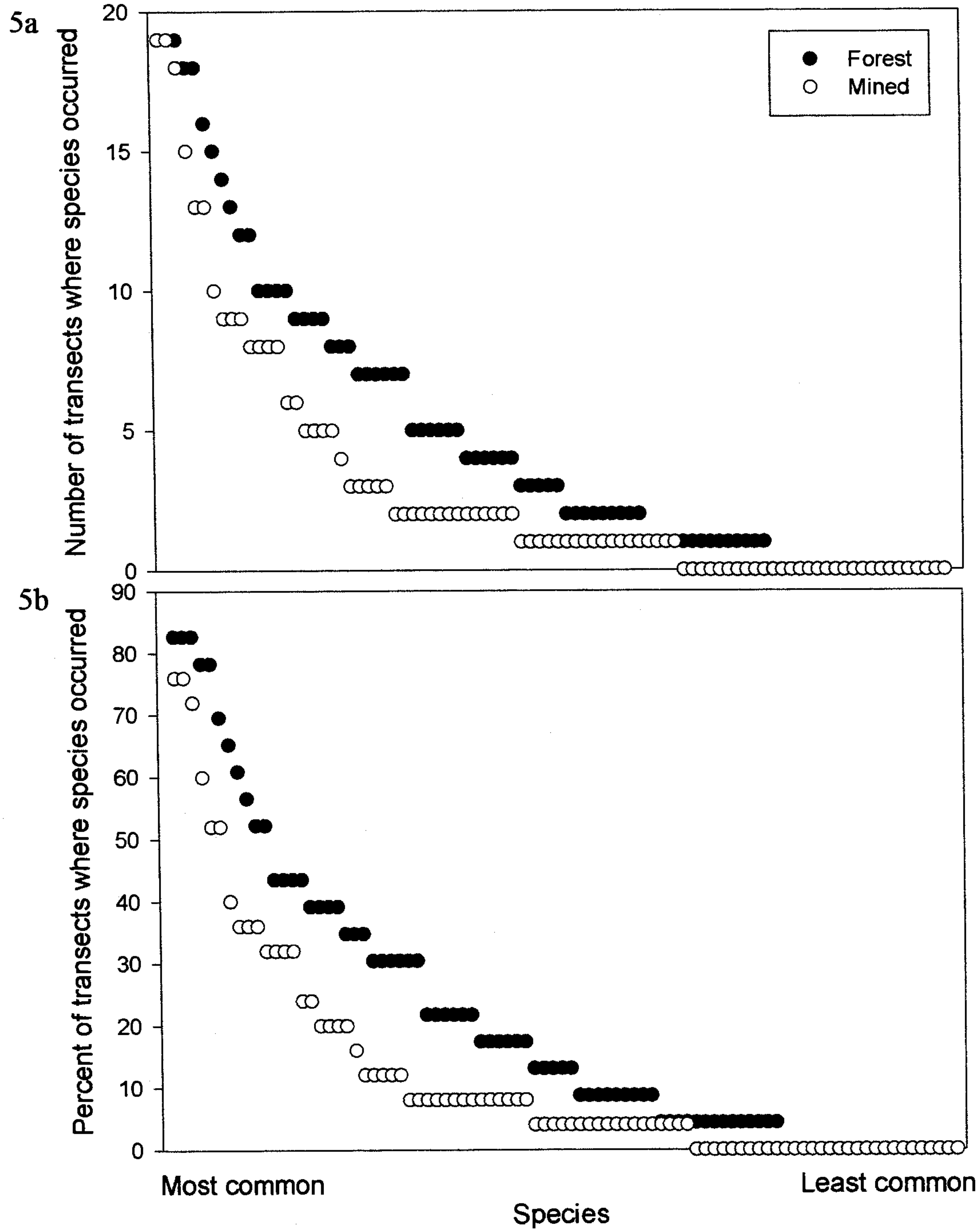


Figure 5a and 5b. Figure 5a on top shows the frequency of occurrence of woody species on 23 forest and 25 mined sites by *number* of transects, while Figure 5b on bottom shows the frequency of occurrence by *percent* of transects. Contour mines are not included.

6a

6b

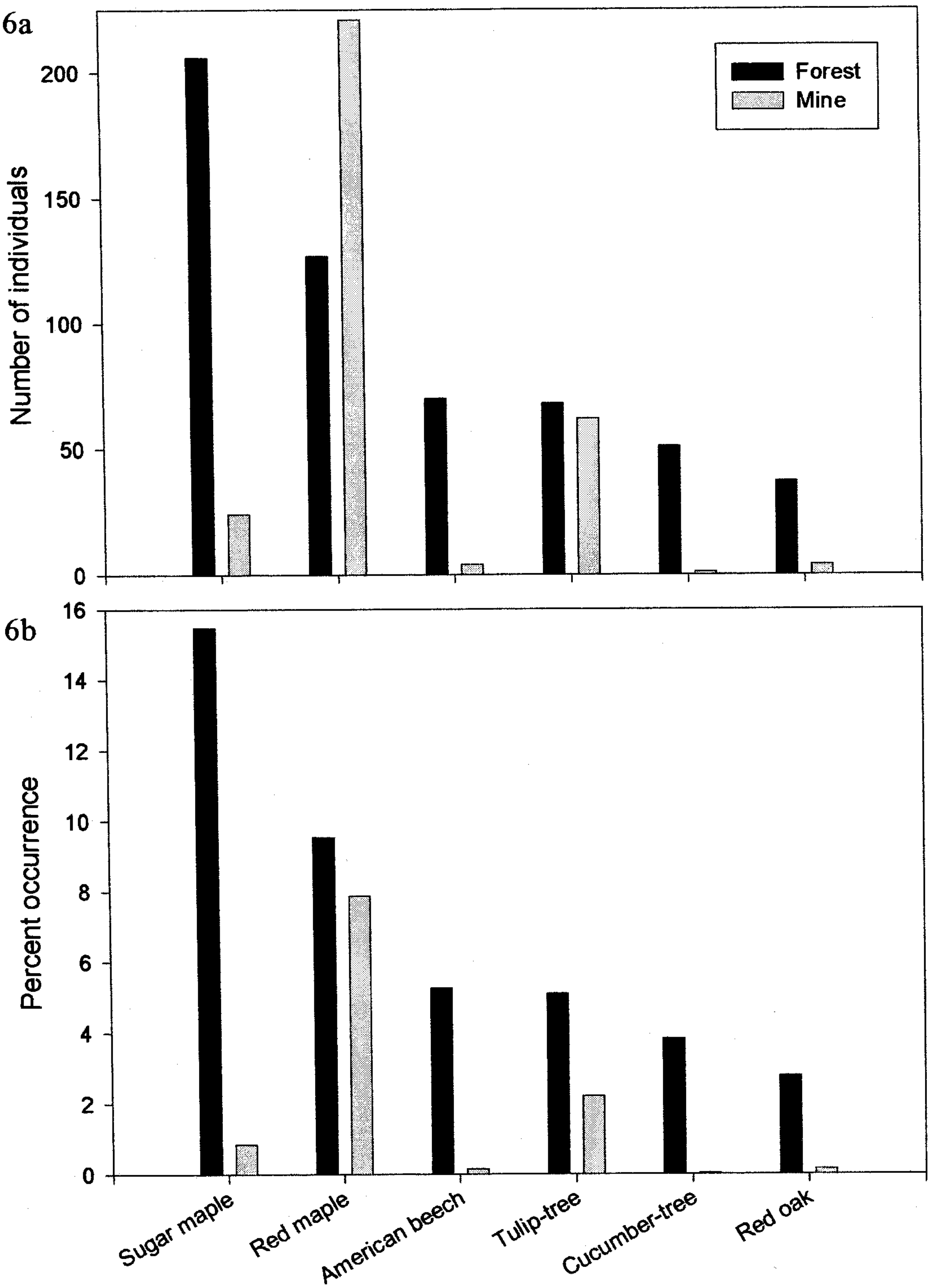


Figure 6a and 6b. Top graph 6a shows the presence of six major forest tree species on forested versus mined areas. Percent occurrence is graphed on the bottom graph, 6b, for the six tree species (of total 1332 forest data points and 2808 mine data points). Contour mine data not included.

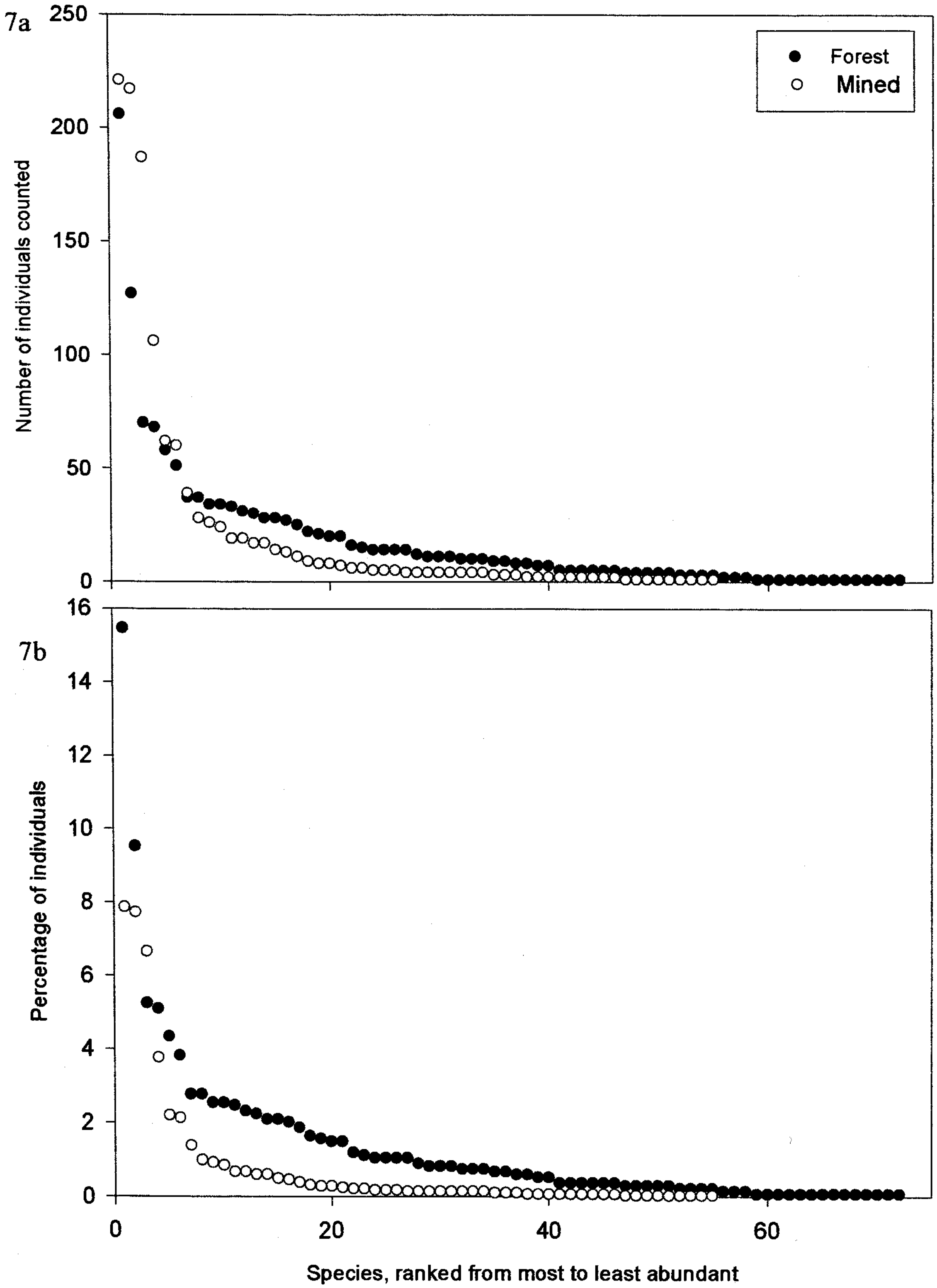


Figure 7a and 7b. Figure 7a illustrates the species abundance distribution, while Figure 7b shows the *percent* species abundance. Based on 1332 forest points and 2808 mined points. Contour mines excluded.

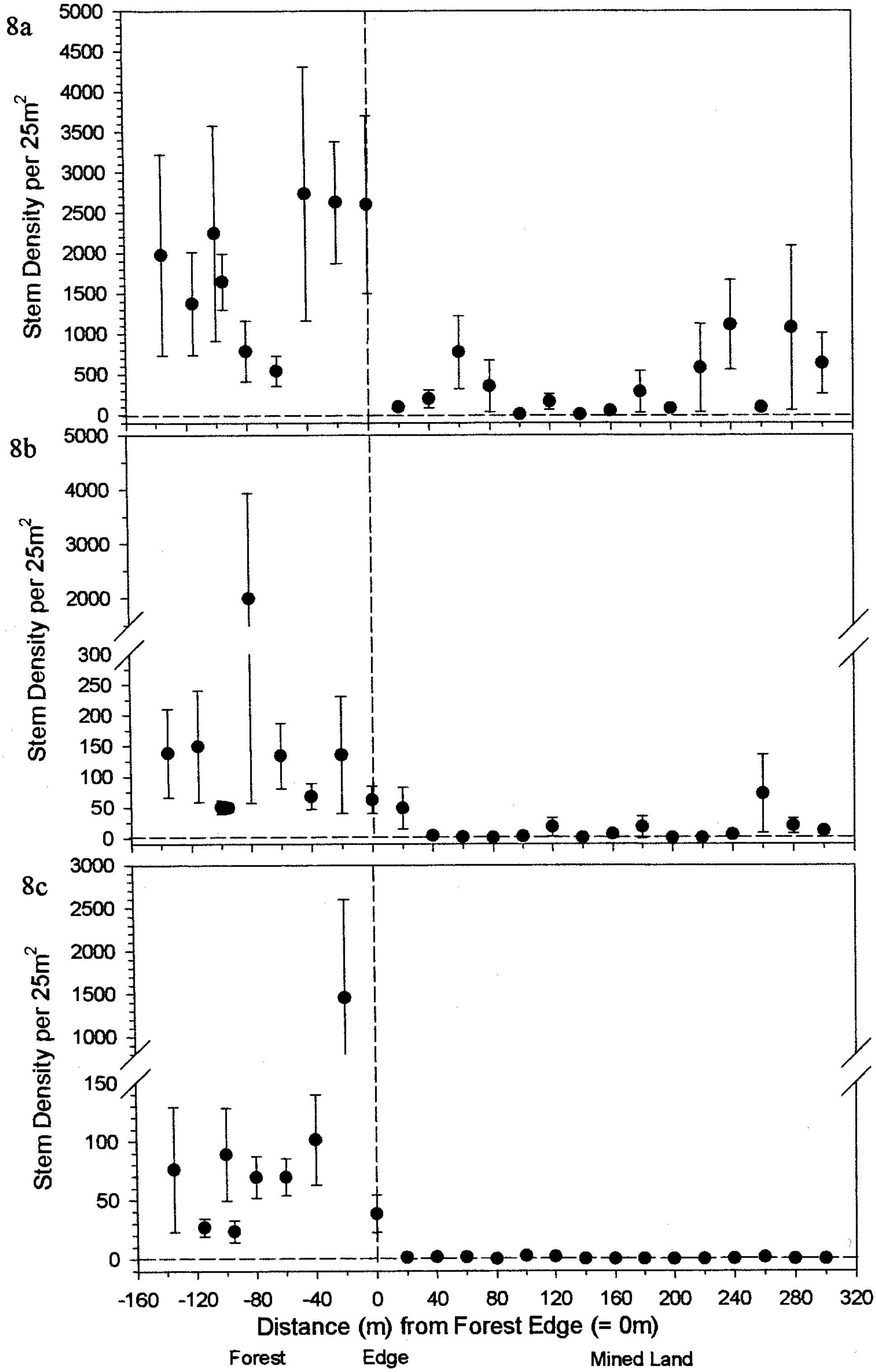


Figure 8a-8c. Mean stem density vs. distance from forest edge for all size classes and mine types. Small woody plants are 1" (2.54cm) and smaller in diameter at base (8a). Medium woody plants are 1-3" (2.54-7.62cm) diameter at base (8b). Large woody plants are 3" (7.62cm) and larger diameter at base (8c). Forest edge is represented by dashed line.

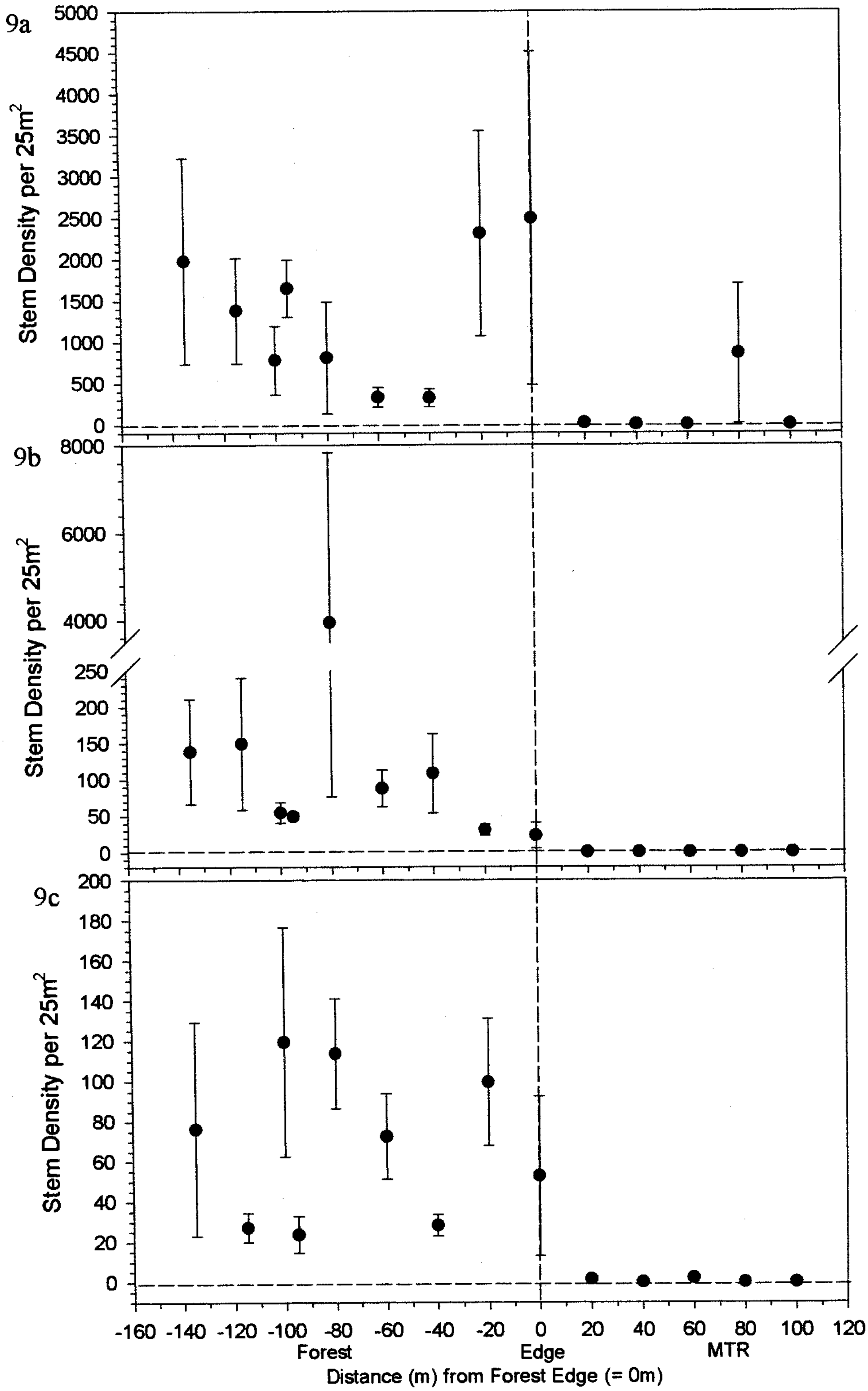


Figure 9a-9c. Mean stem density vs. distance from forest edge in three Mountian-top Removal sites (ages 6, 15,15) and their paired forest remnants. Small woody plants are 1" (2.54cm) or smaller in diameter at base (9a). Medium woody plants are 1-3" (2.54-7.62cm) diameter at base (9b). Large woody plants are 3" (7.62cm) or larger diameter at base (9c). Forest edge is represented by vertical dashed line.

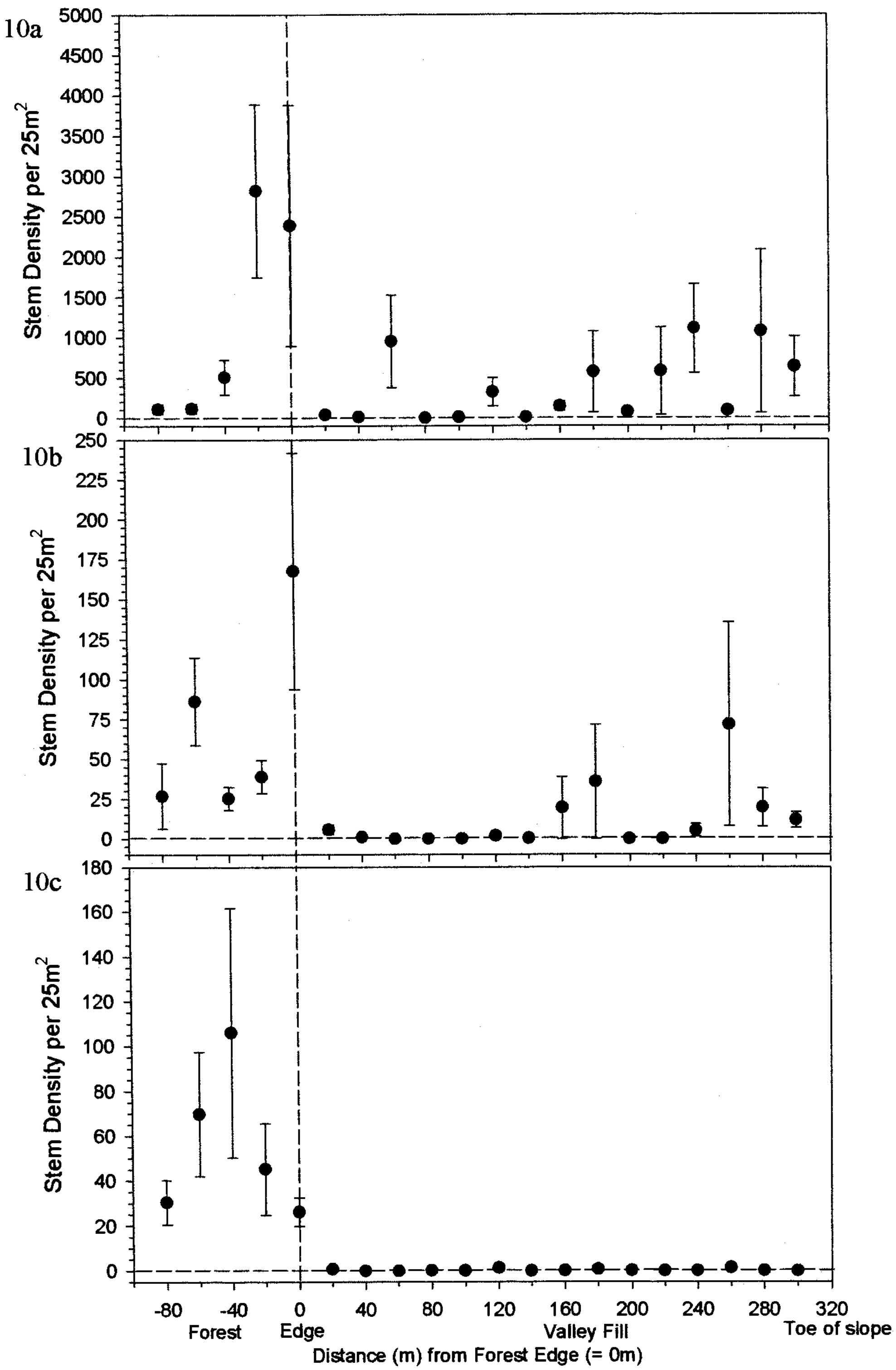


Figure 10a-10c. Mean stem density vs. distance from forest edge in three Valley Fill sites (ages 14, 17, 19) and their paired forest remnants. Small woody plants are 1" (2.54cm) or smaller in diameter at base (10a). Medium woody plants are 1-3" (2.54-7.62cm) diameter at base (10b). Large woody plants are 3" (7.62cm) or larger diameter at base (10c). Forest edge is represented by vertical dashed line.

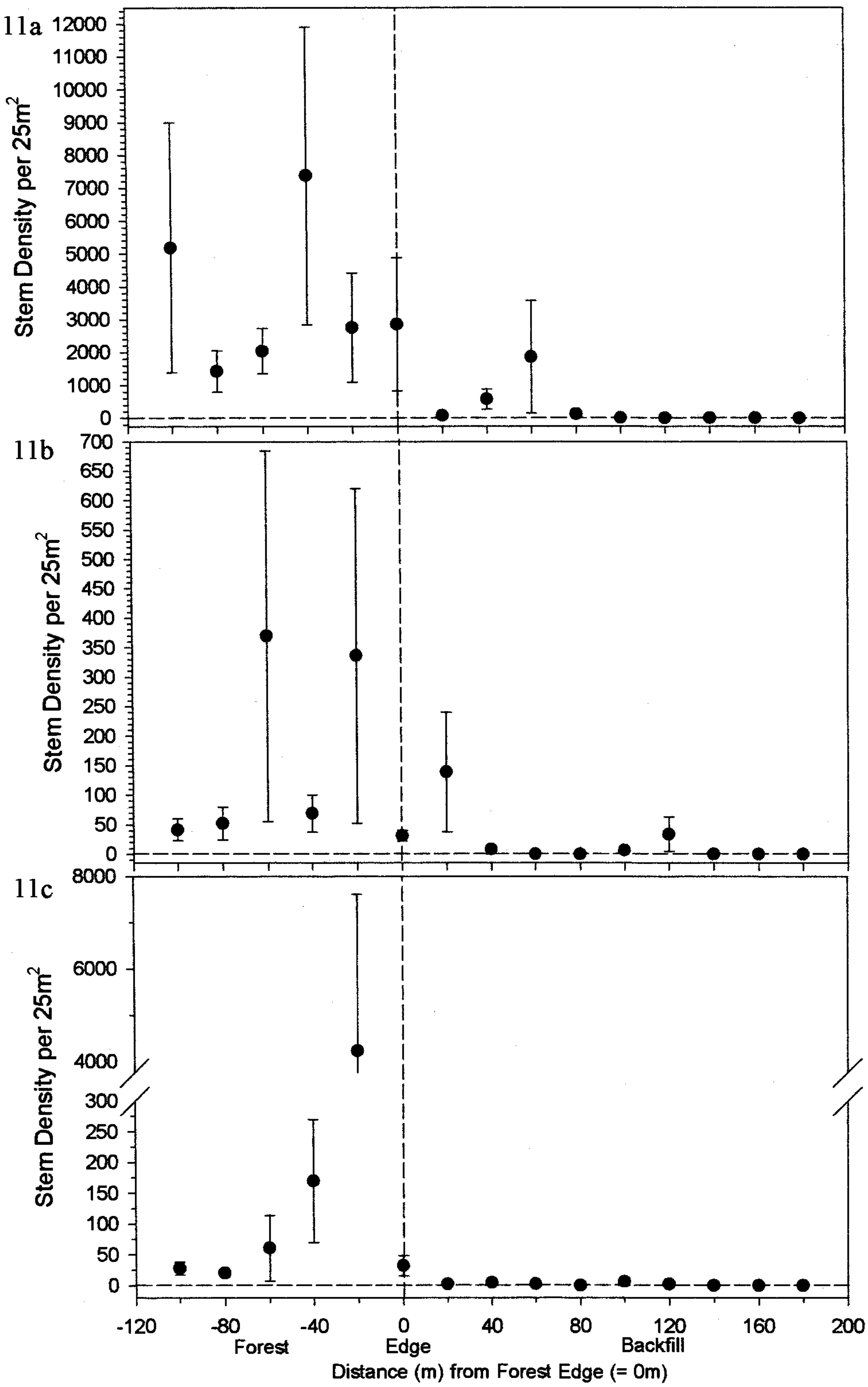


Figure 11a-11c. Mean stem density vs. distance from forest edge in three Backfills (ages 12, 14, 14) and their paired forest remnants. Small woody plants are 1" (2.54cm) or smaller in diameter at base (11a). Medium woody plants are 1-3" (2.54-7.62cm) diameter at base (11b). Large woody plants are 3" (7.62cm) or larger diameter at base (11c). Forest edge is represented by vertical dashed line.

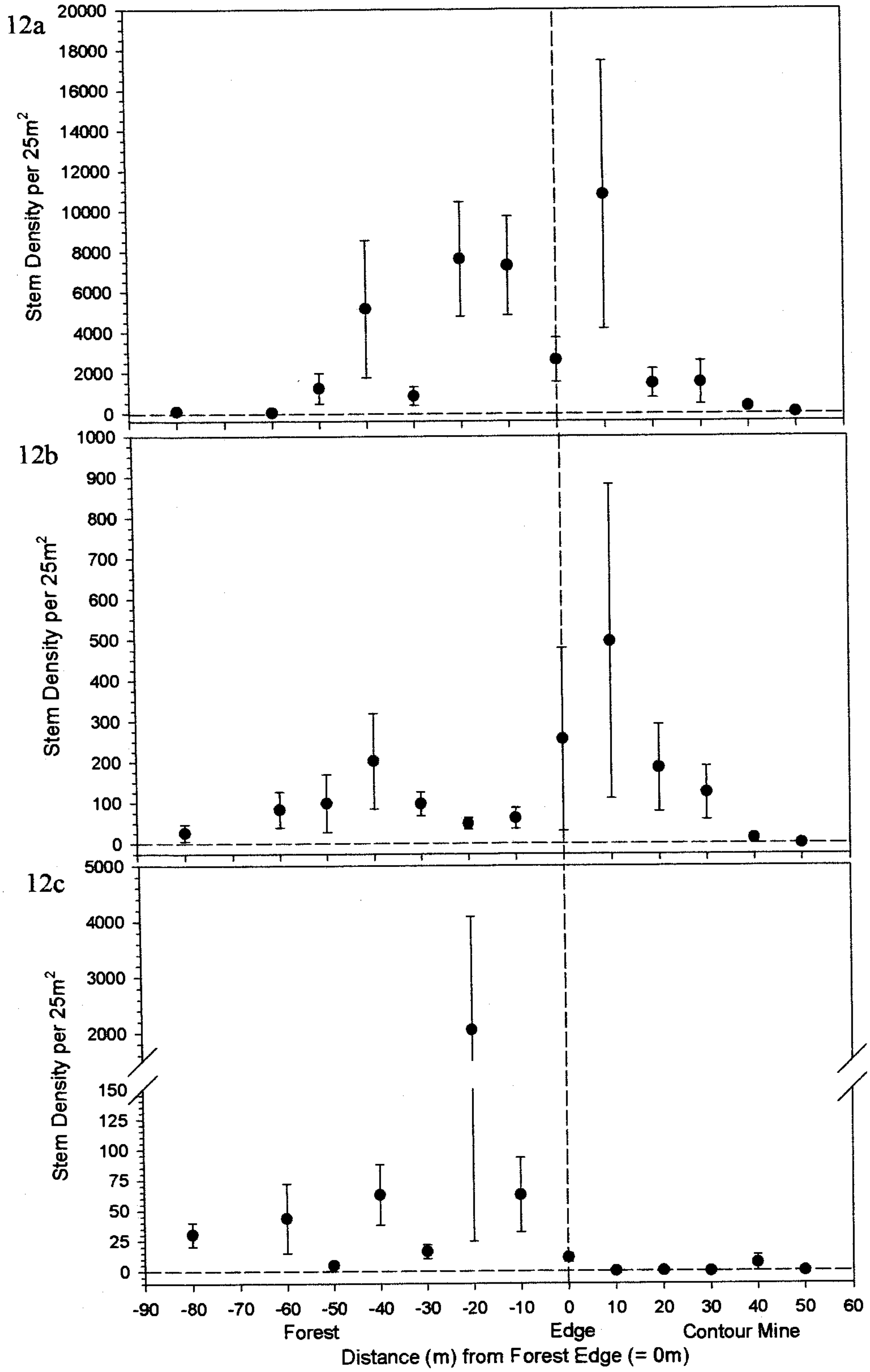
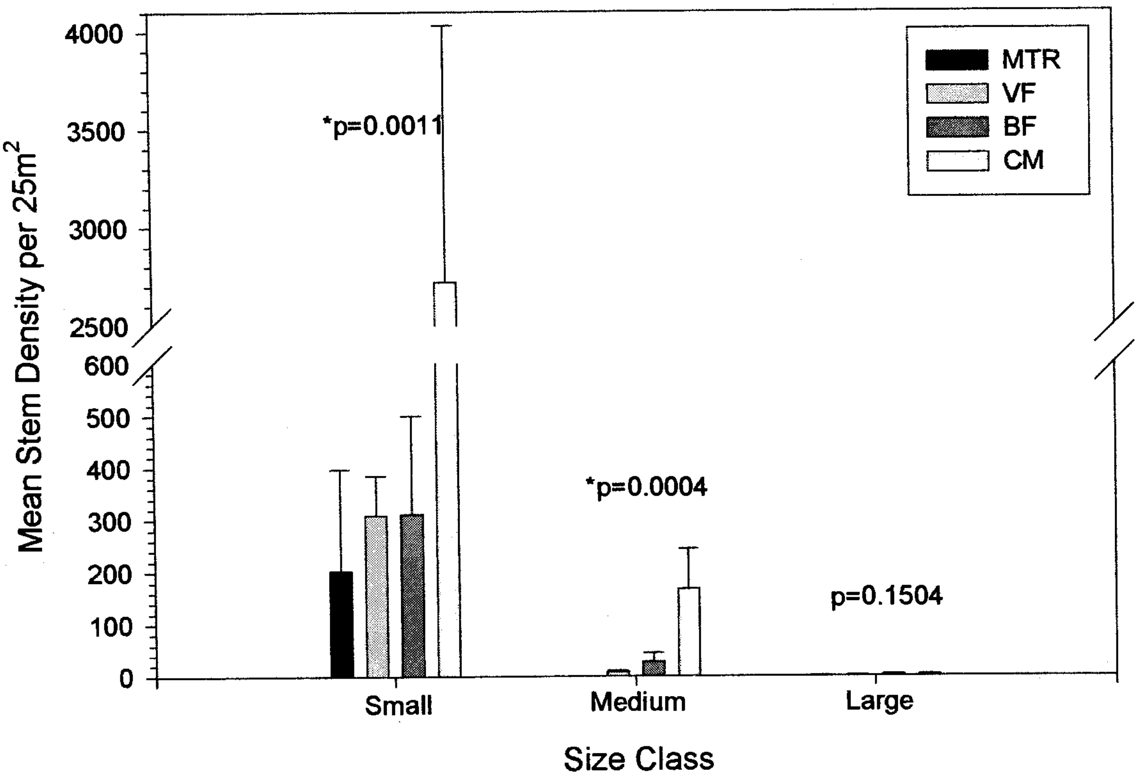


Figure 12a-12c. Mean stem density vs. distance from forest edge for all size classes in three Contour Mines and their paired forest remnants. Small woody plants are 1" (2.54cm) or smaller in diameter at base (12a). Medium woody plants are 1-3" (2.54-7.62cm) diameter at base (12b). Large woody plants are 3" (7.62cm) or larger diameter at base (12c). Forest edge is represented by vertical dashed line.

Figure 13. Mean stem density vs. mine type, by size-class. We tested if mine type differed in density with an analysis of variance for each size class, and compared mean density within size class with Bonferroni adjusted multiple comparisons (Proc GLM in SAS/STAT version 6.12; SAS 1990). Contour mines were significantly different than all other mine types in the small and medium size classes.



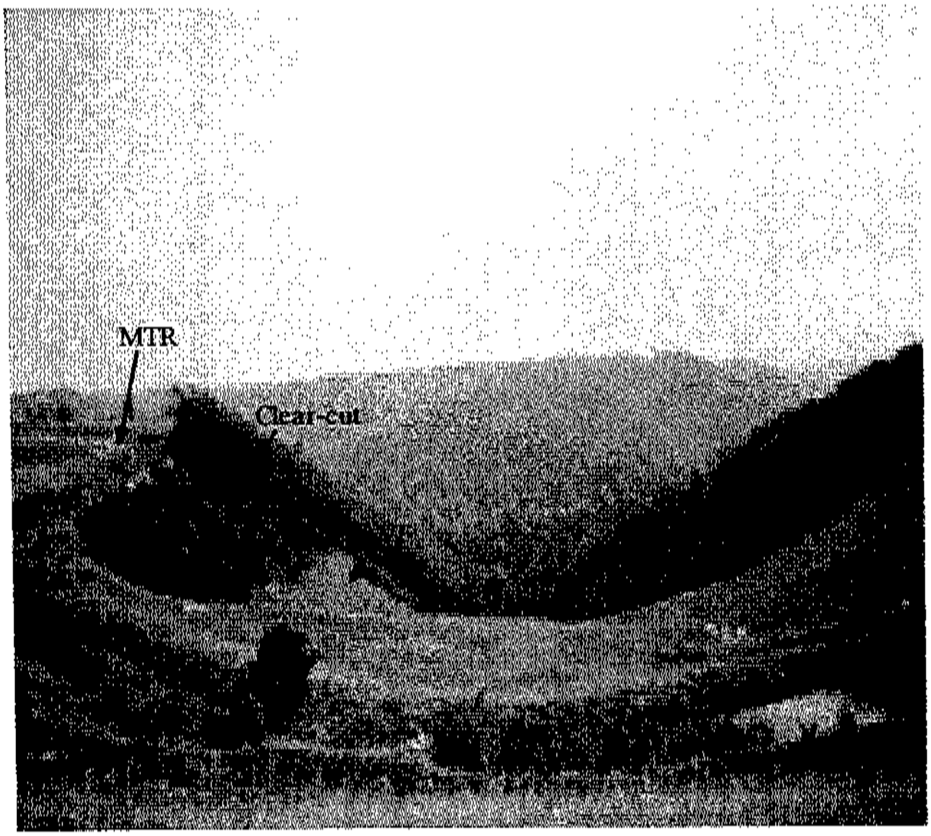


Figure 14a. Peerless Eagle site. MTR on top, then clear-cut, then VF. Taken summer 2000.

Figure 14b. Peerless Eagle Transect. Stem density vs. distance. This is a unique site, with a mountain-top removal at the top of slope, moving into a clear-cut remnant forest and into a valley fill. Age estimated to be 12-15 years.

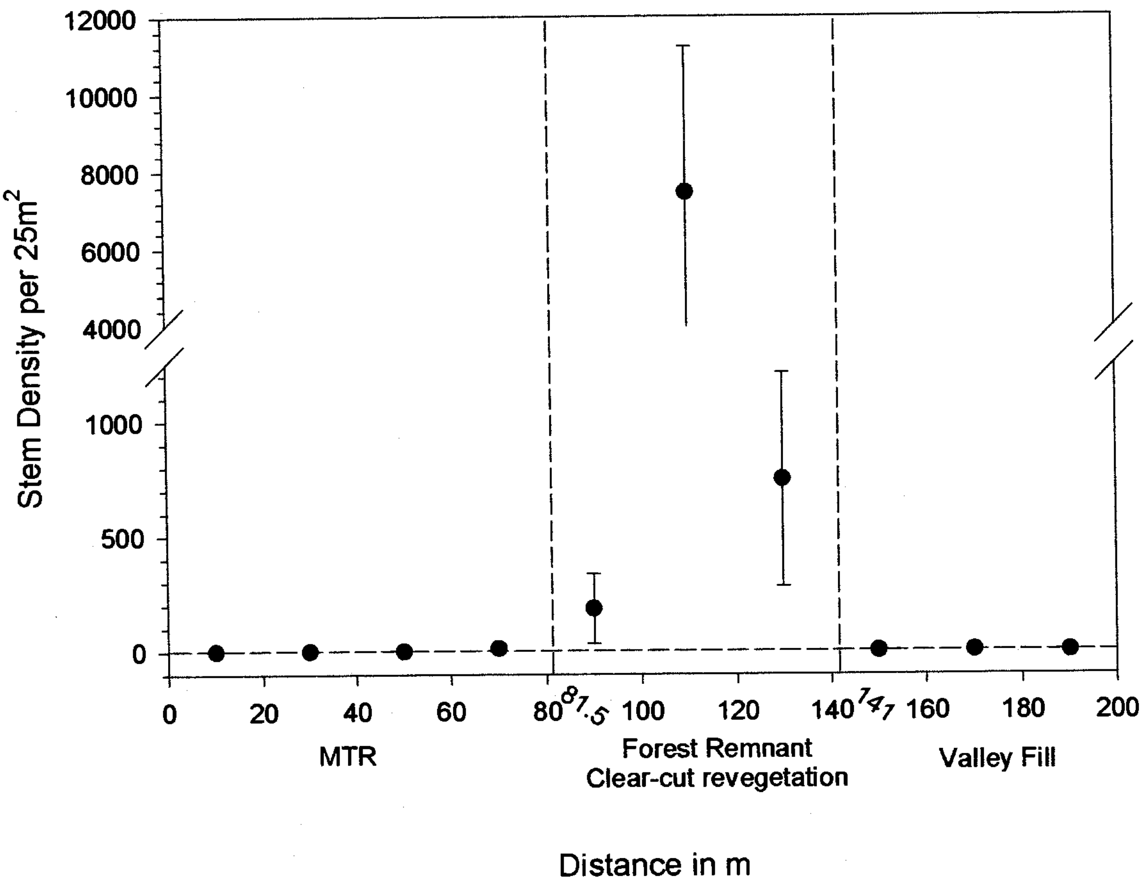
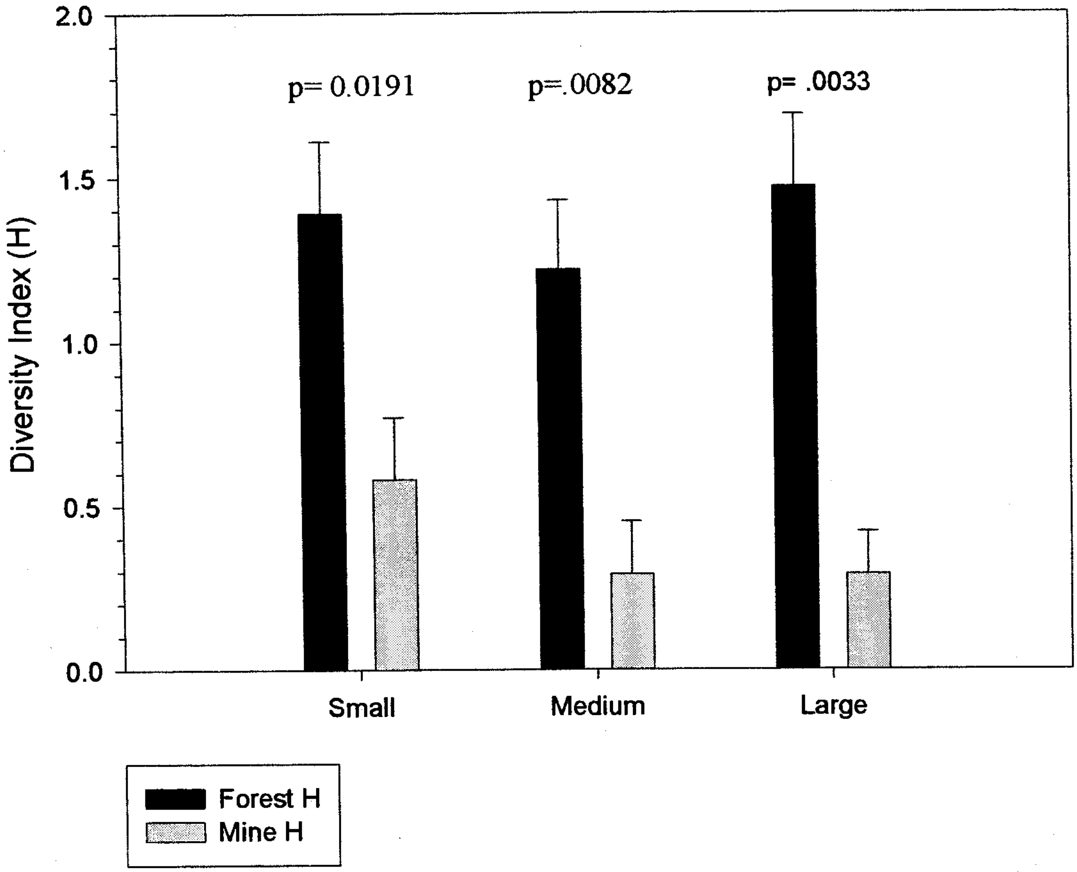
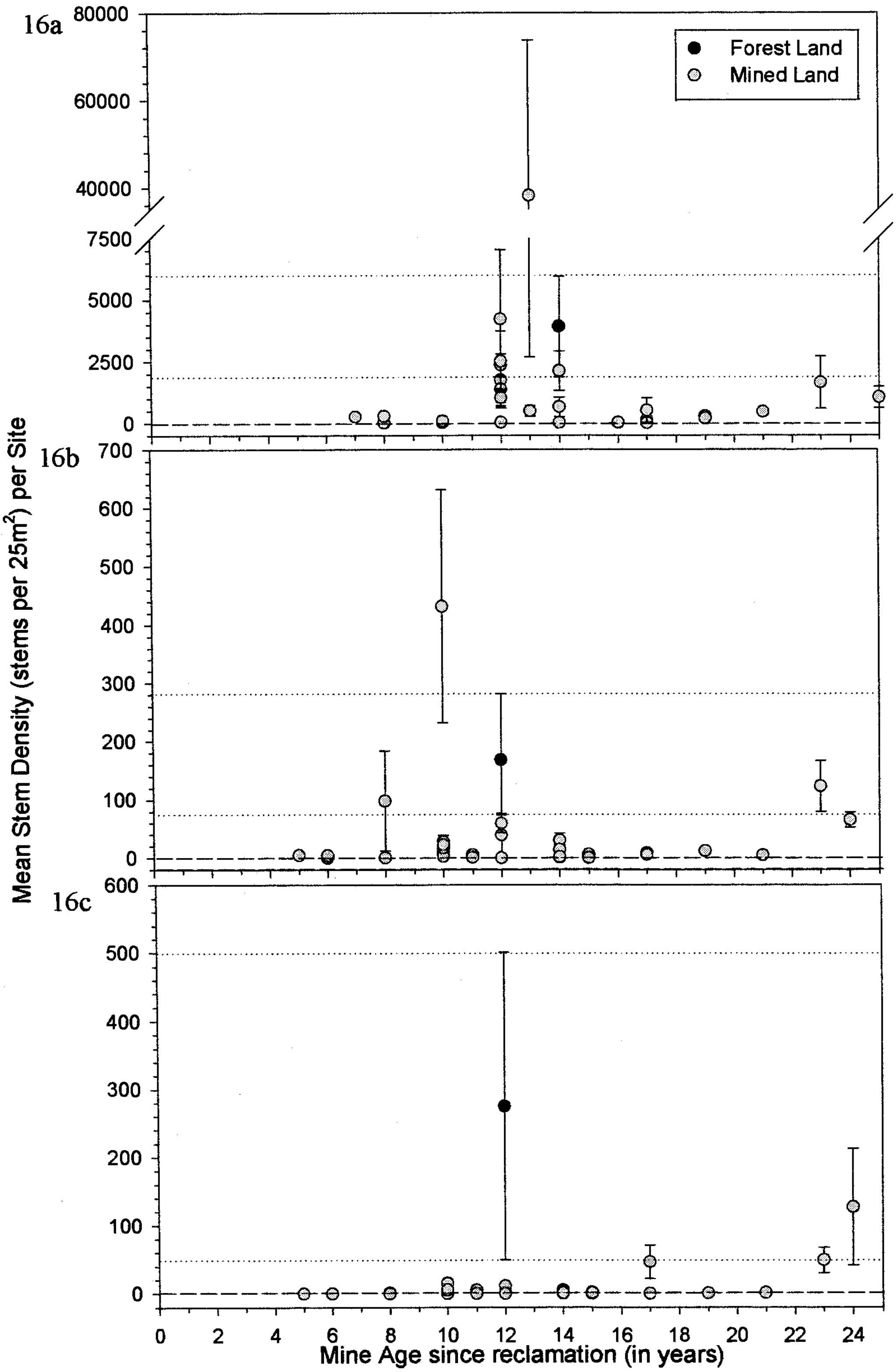
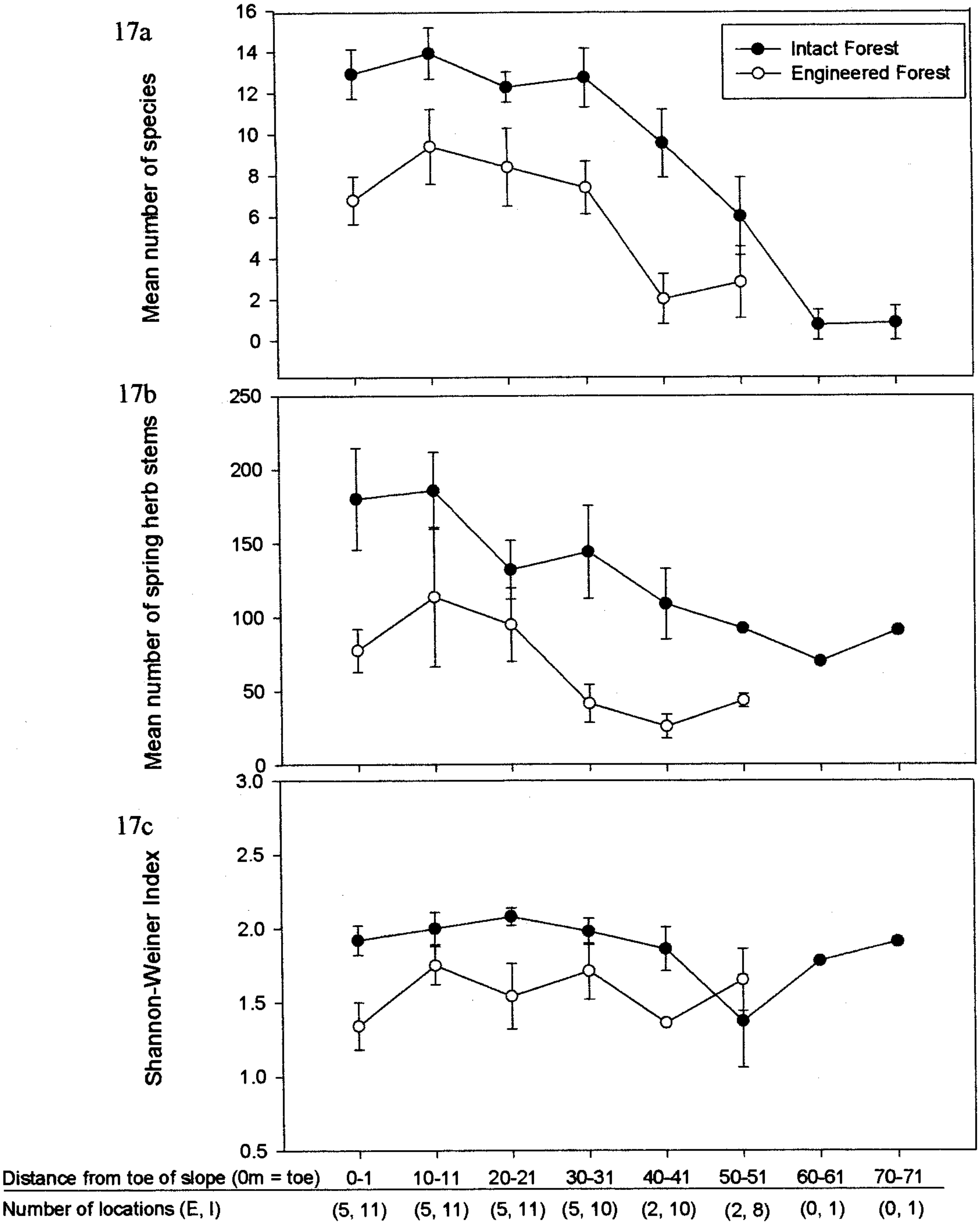


Figure 15. Shannon-Weiner diversity Index (H) for woody trees in all three size classes. Comparison of mined lands to forest remnants (contour mines excluded). A paired t test was performed with df= 8, t (small) = 2.92, t (medium) = 3.49, t (large) = 4.13.





Figures 16a, 16b, 16c. Site age vs. mean stem densities of 30 mined sites compared to the average of 25 forest remnants. Forest mean is displayed between the dotted lines (standard error bars). Age is not implied for forest sites. Small size-class on top (16a), then medium (16b) and large (16c).



Figures 17a-17c. Mean number of spring herb species (17a), stems (17b), and estimate of biodiversity (H) (17c) for spring understory herbs in engineered forested and intact forested sites vs. distance from toe of slope. Two-way ANOVA results: treatment effect in 17a p=0.0001, 17b p= 0.0016, 17c p=0.0030; distance effect 17a p=0.0001, 17b p=0.125, 17c p=0.0989; treatment and distance effect 17 a p=0.26, 17b p=0.9, 17c p=0.3680.

Figure 18. Diagram of mining activity eliminating toe of slope, compared to an intact forest's position of toe. This situation is hypothetical. All values are arbitrary. Dashed line indicates valley fill. Brackets indicate area sampled.

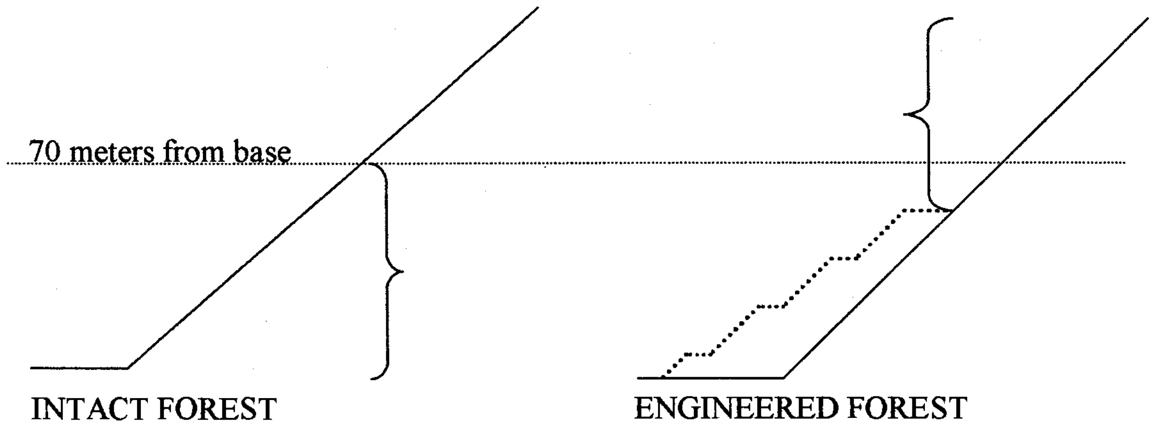


Table 1. West Virginia woody plant study sites. Age equals years since revegetation and were calculated for 2002.

Transect Number	Site Name	County	Site Type	Paired Samples	Site Age	# Spp Found	Planted
1	Colony Bay: Cazy remnant forest	Boone/Logan line	RF	*	—	16	—
2	Colony Bay: Cazy VF	Boone/Logan line	VF	*	21	15	Y
3	Colony Bay: forest remnant	Boone/Logan line	RF		—	22	—
4	Colony Bay: planted slope VF	Boone/Logan line	VF		7	22	Y
5	Colony Bay: WVU plots	Boone/Logan line	VF		17	14	Y
6	Daltex Mine: continuous forest - MT 32	Logan	CF		—	23	—
7	Daltex Mine: Zapata remnant forest	Logan	RF		—	19	—
8	Daltex Mine: Zapata VF	Logan	VF		25	19	Y
9	Hobet Mine: continuous forest	Lincoln	CF		—	15	—
10	Hobet Mine: Bragg Fork plateau	Lincoln	VF	**	25	4	Y
11	Hobet Mine: Bragg Fork remnant forest	Lincoln	RF	**	—	20	—
12	Hobet Mine: Bragg Fork VF	Lincoln	VF		25	11	Y
13	Hobet Mine: Lick Creek MTR	Lincoln	MTR		13	8	Y
14	Hobet Mine: Lick Creek remnant forest	Lincoln	RF		—	15	—
15	Hobet Mine: Lick Creek VF	Lincoln	VF		13	12	Y
16	Hobet Mine: Stanley Fork MTR	Lincoln	MTR	***	8	11	Y
17	Hobet Mine: Stanley Fork remnant forest	Lincoln	RF	***	—	26	—
18	Hobet Mine: Stanley Fork VF	Lincoln	VF		8	12	Y
19	Island Creek: L	Nicholas	BF	◆	14	10	N
20	Island Creek: L remnant forest	Nicholas	RF	◆	—	25	—
21	Island Creek: R	Nicholas	BF		14	15	N
22	Island Creek: Valley fill	Nicholas	VF		14	6	Y
23	Leckie Smokeless: Briery Knob cluster planting	Greenbrier	MTR	◆◆	17	2	Y
24	Leckie Smokeless: Briery Knob cluster planting rem. for.	Greenbrier	RF	◆◆	—	18	—
25	Leckie Smokeless: Briery Knob forest strip	Greenbrier	RF	◆◆◆	—	8	—
26	Leckie Smokeless: Briery Knob prairie	Greenbrier	MTR	❖	17	4	N
27	Leckie Smokeless: Briery Knob prairie remnant forest	Greenbrier	RF	❖	—	16	—
28	Leckie Smokeless: Briery Knob remnant forest	Greenbrier	RF	❖❖	—	17	—
29	Leckie Smokeless: Briery Knob ROPS backfill	Greenbrier	BF	◆◆◆	16	1	Y
30	Leckie Smokeless: Briery Knob VF	Greenbrier	VF	❖❖	16	3	N
31	Leckie Smokeless: Pollock Knob 1	Greenbrier	BF	❖❖❖	16	5	Y
32	Leckie Smokeless: Pollock Knob 1 remnant forest	Greenbrier	RF	❖❖❖	—	11	—
33	Leckie Smokeless: Pollock Knob 2	Greenbrier	BF		16	4	Y
34	Lodestar Energy: MT 75 remnant forest	Raleigh	RF		—	23	—
35	Lodestar Energy: MT 75 VF - "Green Heron Pond"	Raleigh	VF		10	13	Y
36	Peerless Eagle Mine: remnant forest	Nicholas	RF		—	13	—
37	Peerless Eagle Mine: valley fill	Nicholas	VF		???	17	N
38	Pen Coal: 3 Remnant forest	Lincoln/Wayne line	RF	■	—	12	—
39	Pen Coal: Alnus	Lincoln/Wayne line	CM	■■	12	12	Y
40	Pen Coal: Alnus remnant forest	Lincoln/Wayne line	RF	■■	—	16	—
41	Pen Coal: continuous forest	Lincoln/Wayne line	CF		—	19	—
42	Pen Coal: Elaeagnus	Lincoln/Wayne line	CM		12	10	Y
43	Pen Coal: Frank Branch Pond site	Lincoln/Wayne line	CM	■■■	12	6	Y
44	Pen Coal: Frank Branch remnant forest	Lincoln/Wayne line	RF	■■■	—	25	—
45	Pen Coal: no planting 3L	Lincoln/Wayne line	CM		12	19	N
46	Pen Coal: no planting 3R	Lincoln/Wayne line	CM	■	12	13	N
47	Pen Coal: VF Robinia	Lincoln/Wayne line	VF		12	15	Y
48	Pigeon Roost: continuous forest - MT 45	Logan	CF		—	22	—
49	Rockhouse: continuous forest- MT 25B	Logan/Boone line	CF		—	20	—
50	Sample Mine: Mynu VF	Kanawha/Boone line	VF		26	22	Y
51	Samples Mine: Mynu remnant forest	Kanawha/Boone line	RF		—	16	—
52	Wylo Mine: Amherst remnant forest	Logan	RF		—	19	—
53	Wylo Mine: Amherst VF	Logan	VF		23	20	Y
54	Wylo Mine: Amherst VF2	Logan	VF		10	14	N
55	Wylo Mine: remnant forest 2	Logan	RF		—	17	—

Table 1 (Con't)

Transect Number	Date Visited	Site Characterization
1	20-Sep	A continuation from VF transect into woods
2	20-Sep	*Robinia pseudoacacia, Eleagnus umbellata, Paulownia tomentosa* planted; longest landfill (1.2miles)
3	19-Sep	Located adjacent to VF
4	19-Sep	Slopes planted w/ different sp; olive, alder, locust, oak, sycamore, crabapple, persimmon, pine; RoPs seeded
5	20-Sep	WVU experiment w/ treatments;*R. pseudoacacia, P. virginiana, P. strobus, Quercus sp, A. glutinosa* planted
6	22-Jul	Roadside site, behind retention pond; same site as spring sampling (site w/ electrical lines running through)
7	17-Jul	Forest remnant located adjacent to VF
8	17-Jul	*Eleagnus umbellata* & *Robinia pseudoacacia* plantings
9	23-Jul	Transect started at top of forested slope; dry woods, little leaf litter
10	20-Jul	Plateau very compact from trucks filling BFs; located below RFs; very large & long VF hydroseeded w/ RoPs
11	20-Jul	Forest remnant is adjacent to VF
12	20-Jul	hydroseeded w/ *Robinia pseudoacacia*
13	22-Jun	MTR continues into RF below (VF is adjacent); planted w/ *Fraxinus* sp (not doing well) & *E. umbellata*
14	23-Jun	Transect runs up from VF bottom, through forest.
15	23-Jun	Transect runs down VF w/ forest at base; planted w/ *Pinus virginiana, Eleagnus umbellata, Fraxinus* sp
16	22-Jun	Above the forest remnant transect; 7 rows of *Eleagnus umbellata* planted
17	22-Jun	Transect is adjacent to fill, runs up slope through forest and continues through MTR site above
18	22-Jun	*Eleagnus umbellata* planted in blocks, on slopes as opposed to terraces
19	21-Aug	Rolling, grass dominated backfill; not planted, forest remnant at top
20	21-Aug	Forest remnant at top of transect L
21	21-Aug	RF's at top and to side; not planted
22	21-Aug	*Robinia pseudoacacia* and *Alnus glutinosa* plantings
23	19-Aug	Experimental Westvaco plantings include Aspen, Pine hybrids, *Alnus glutinosa*; large, flat MTR site
24	19-Aug	A continuation of the MTR transect, located to the right of the cluster plantings,
25	17-Aug	A very thin forest strip (37m wide) located above the backfill
26	19-Aug	Not planted w/ woodies
27	19-Aug	Located to the left of the prairie; a very flat forest
28	17-Aug	Forest remnant located below the VF & small abondoned road
29	17-Aug	Hydroseeded *Robinia pseudoacacia*, continues up from VF transect
30	17-Aug	A continuation of the remnant forest below; dense grass cover, no plantings
31	20-Aug	Rolling refuse hills; top planted w/ pine, *Alnus glutinosa, Eleagnus umbellata, Robinia pseudoacacia*
32	20-Aug	A continuation of the rolling refuse hill transect, at top of hill
33	20-Aug	*Robinia pseudoacacia* & pine planted
34	18-Aug	Located across the county road from the VF site
35	15-Aug	Robinia pseudoacacia planting
36	22-Aug	Forest remnant located next to "unique" transect
37	22-Aug	Unique site = BF, then regenerating cut, then VF; not planted
38	17-Jun	Forest remnant located above transect 3R
39	18-Jun	*Alnus glutinosa* planted in blocks, transect runs through blocks, gaps b/t planting blocks & forest edge
40	18-Jun	A continuation of above CM transect, into woods
41	24-Jul	CF transect found on edge of mine property, by offices
42	17-Jun	*E. umbellata* planted in 37m wide block; transect runs through block; gap b/t planting block & forest edge
43	14-Jun	CM located below forest remnant; top of slope planted very densely w/ *Eleagnus umbellata*
44	14-Jun	A continuation of above contour mine transect, into forest; *Eleagnus umbellata* block comes to forest edge
45	16-Jun	Transects 3L and 3R are 25m apart, w/ RF above them; CM not planted w/ woodies
46	17-Jun	Transects 3L and 3R are 25m apart, w/ RF above them; CM not planted w/ woodies
47	15-Jun	A VF with terraces planted with *Robinia pseudoacacia*
48	22-Jul	Same site as spring site
49	23-Jul	Not same site as spring sample, but was at a stream sample point.
50	18-Jul	Retention pond at base, VF is adjacent to forest; planted w/ *Robinia pseudoacacia*
51	18-Jul	Forest remnant is adjacent to VF
52	21-Jul	Forest remnant located adjacent to fill
53	19-Jul	Planted w/ scattered fruit trees & *Robinia pseudoacacia*
54	25-Jul	A very large VF, not planted
55	25-Jul	Forest remnant located adjacent to fill

Table 2. West Virginia spring herbaceaous study sites (2000).

(m) = mine
(both) = mine and forest
(f) = forest
*** = no stem count conducted

Site #	Site name	County	Engineered	# Spp Found	# Stems	Date Visited
1	Cabin Creek MT51	Logan	N	28	547	4/24/2000
2	White Oak MT 39	Logan	N	29	1401	4/25/2000
3	Old House Branch MT 42	Logan	N	35	784	4/25/2000
4	Pigeon Roost	Logan	N	28	1115	4/25/2000
5	Spruce Forks Mine, Left fork of Beach Creek MT32	Logan	Y	20	323	4/25/2000
6	Rockhouse Creek VF	Logan	Y	16	***	4/25/2000
7	Cow Creek, MT 107	Logan	N	27	739	4/26/2000
8	Cow Creek Roadside Mt 52	Logan	Y	26	335	4/26/2000
9	Spruce Forks Mine roadside/RR side site B	Logan	Y	27	650	4/27/2000
10	Mud River VF + forest edge transect	Boone	Y	14	117	4/27/2000
11	Mud River VF	Boone	Y	12	***	4/27/2000
12	Site 2	Raleigh	N	28	609	5/1/2000
13	Lodestar Energy: MT 75	Raleigh	Y	15(m), 5(both), 9(f)	***	5/2/2000
14	Buffalo Fork	Raleigh	N	21	213	5/2/00
15	Toney Fork	Raleigh	N	26	441	5/2/2000
16	Hughes Fork	Kanawha	N	28	514	5/3/2000
17	Twentymile Creek	Kanawha	Y	28	349	5/3/2000
18	Peerless Eagle: Radar Fork	Nicholas	N	33	1446	5/4/2000
19	Peerless Eagle: Neff	Nicholas	N	35	1204	5/4/2000

Site #	Site characteristics
1	lots of litter, old trees, healthy seedling & sapling cover
2	very rich & complete woods
3	lots of moss, moist woods
4	rich site; lots of herbivore damage
5	potential edge effect location for woody invasion
6	VF invasion site; RF was located above VF; in a 20m wide swath down the 68m slope, no woodland herbs were invading
7	sunny, cool slope
8	sunny, unmined slope
9	very degraded site... VF above & all over, tons of vines & weeds; large thicket under powerlines preventing further sampling
10	very sunny, dry, open slope w/ planted olive, lots of leaf litter, many grass spp; no woodland invaders 50+ m up VF
11	woody vegetation; very sunny, dry, open slope w/ planted olive, many grass spp, thickets
12	much herbivory at this site, heavy litter w/ many seedlings & saplings
13	VF area, mostly grasses & planted black locust, white pine
14	cow pasture nearby
15	very sunny, fairly open forest; very rich and large floodplain
16	very different forest from others so far, full of hemlock & rhododendron, rich, mesic
17	very dry, disturbed area, not many species, lots of sassafras seedlings/saplings
18	very dark, mesic forest
19	across road from stream, off left of main haul road, down the smaller log road some distance on right

Table 3. List of woody species found on West Virginia study transects (**a** indicates alien species)

	SCIENTIFIC NAME	COMMON NAME
	Acer negundo	Boxelder
	Acer pensylvanicum	Striped maple
	Acer rubrum	Red maple
	Acer saccharum	Sugar maple
	Aesculus octandra	Yellow buckeye
	Aesculus sp.	Buckeye
a	*Ailanthus altissima**	Tree-of-heaven
a	*Albizzia julibrissin**	Silk tree, mimosa
a	*Alnus glutinosa**	Black alder
	Amelanchier arborea	Downy serviceberry
	Amelanchier sp.	Serviceberry, shadbush
	Aristolochia macrophylla	Dutchman's pipe
	Azalea sp.	Azalea
	Betula alleghaniensis	Yellow birch
	Betula lenta	Black birch
	Betula sp.	Birch
	Carpinus caroliniana	Musclewood, ironwood
	Carya cordiformis	Bitternut hickory
	Carya glabra	Pignut hickory
	Carya ovata	Shagbark hickory
	Carya sp.	Hickory
	Carya tomentosa	Mockernut hickory
	Castanea dentata	American chestnut
	Cercis canadensis	Redbud
	Cornus florida	Flowering dogwood
	Corylus americana	American hazelnut
	Crataegus sp.	Hawthorne
a	*Eleagnus umbellata**	Autumn olive
	Epigaea repens	Trailing arbutus
	Fagus grandifolia	American beech
	Fraxinus americana	White ash
	Fraxinus nigra	Black ash
	Fraxinus pennsylvanica	Red ash
	Fraxinus sp.	Ash
	Hamamelis virginiana	Witch hazel
	Hydrangea arborescens	American hydrangea
	Hydrangea sp.	Hydrangea
	Juniperus virginiana	Eastern red cedar
	Kalmia latifolia	Mountain laurel
a	*Lespedeza bicolor**	Japanese bush clover
	Lindera benzoin	Spice-bush
	Liriodendron tulipifera	Tulip-tree, yellow poplar
a	*Lonicera japonica**	Japanese honeysuckle
	Magnolia acuminata	Cucumber-tree
	Magnolia grandiflora	Southern magnolia
	Magnolia fraseri	Mountain magnolia
a	*Magnolia soulangeana**	Saucer magnolia
	Magnolia tripetala	Umbrella-tree
	Magnolia virginiana	Sweetbay magnolia
	Morus sp.	Mulberry
	Oplopanax horridus	Devil's club, Devil's walking stick
	Ostrya virginiana	Hop-hornbeam
	Oxydendrum arboreum	Sourwood
	Parthenocissus quinquefolia	Virginia creeper
a	*Paulownia tomentosa**	Princess-tree

Table 3. (con't)

	Pinus echinata	Shortleaf pine
	Pinus resinosa	Red pine
	Pinus rigida	Pitch pine
	Pinus strobus	White pine
	Pinus virginiana	Scrub pine, Virginia pine
	Platanus occidentalis	Sycamore
	Populus balsamifera	Balsam poplar
	Populus grandidentata	Bigtooth aspen
	Prunus pensylvanica	Fire cherry, Pin cherry
	Prunus serotina	Black cherry
	Prunus sp.	Cherry
	Prunus virginiana	Choke cherry
	Quercus alba	White oak
	Quercus bicolor	Swamp oak
	Quercus coccinea	Scarlet oak
	Quercus marilandica	Black-jack oak
	Quercus prinus	Chestnut oak
	Quercus rubra	Northern red oak
	Quercus velutina	Black oak
	Quercus sp.	Oak
	Rhododendron maximum	Great rhododendron
	Rhus copallinum	Shining sumac
	Rhus glabra	Smooth sumac
	Rhus typhina	Staghorn sumac
	Robinia hispida	Bristly locust
	Robinia pseudoacacia	Black locust
	Rosa caroliniana	Pasture rose
a	*Rosa multiflora**	Multiflora rose
	Rubus allegheniensis	Common blackberry
	Rubus recurviculatus	Dewberry
	Rubus sp.	Bramble
	Sassafras albidum	Sassafras
	Smilax glauca	Saw brier
	Smilax sp.	Catbrier
	Tilia americana	Basswood, American linden
	Toxicodendron radicans	Poison ivy
	Tsuga canadensis	American Hemlock
	Ulmus rubra	Slippery or red elm
	Vaccinium angustifolium	Common lowbush blueberry
	Vaccinium pallidum	Hillside blueberry
	Vaccinium sp.	Blueberry
	Viburnum acerifolium	Maple-leaf viburnum
	Vitis aestivalis	Summer grape
	Vitis sp.	Grape

Table 4: Woody species found on study sites ranked from most to least present. Does not include contour mines. * denotes alien/non-native species

Ranked by most to least common on forest sites.

Transect type	forest total	mined total
Number of transects	23	25
Species		
Acer rubrum	19	18
Acer saccharum	19	9
Quercus rubra	19	2
Liriodendron tulipifera	18	13
Smilax sp.	18	5
Fagus grandifolia	16	3
Parthenocissus quinquefolia	15	8
Rubus sp.	14	19
Betula lenta	13	9
Toxicodendron radicans	12	9
Magnolia acuminata	12	2
Vitis sp.	10	5
Cornus florida	10	3
Tilia americana	10	2
Viburnum acerifolium	10	0
Fraxinus pennsylvanica	9	10
Carya cordiformis	9	0
Carpinus caroliniana	9	0
Acer pensylvanicum	9	0
Oxydendrum arboreum	8	13
Prunus serotina	8	6
Lindera benzoin	8	0
Robinia pseudoacacia	7	19
Sassafras albidum	7	1
Quercus alba	7	1
Magnolia tripetala	7	1
Cercis canadensis	7	1
Hamamelis virginiana	7	0
*Ailanthus altissima**	5	3
Vaccinium sp.	5	2
Quercus prinus	5	2
Hydrangea arborescens	5	1
Ostrya virginiana	5	0
Carya glabra	5	0
Betula alleghaniensis	4	4
Quercus velutina	4	1
Quercus marilandica	4	0
Carya tomentosa	4	0
Carya ovata	4	0
Aesculus octandra	4	0
Magnolia virginiana	3	0
*Magnolia soulangeana**	3	0
Magnolia fraseri	3	0
Crataegus sp.	3	0
Carya sp.	3	0
*Eleagnus umbellata**	2	15
*Rosa multiflora**	2	8

Ranked by most to least common on mined sites.

forest total	mined total	Transect type
23	25	Number of transects
		Species
14	19	*Rubus sp.*
7	19	*Robinia pseudoacacia*
19	18	*Acer rubrum*
2	15	*Eleagnus umbellata**
18	13	*Liriodendron tulipifera*
8	13	*Oxydendrum arboreum*
9	10	*Fraxinus pennsylvanica*
19	9	*Acer saccharum*
13	9	*Betula lenta*
12	9	*Toxicodendron radicans*
15	8	*Parthenocissus quinquefolia*
2	8	*Prunus sp.*
2	8	*Rosa multiflora**
1	8	*Platanus occidentalis*
8	6	*Prunus serotina*
0	6	*Lespedeza bicolor**
18	5	*Smilax sp.*
10	5	*Vitis sp.*
1	5	*Rhus typhina*
0	5	*Alnus glutinosa**
4	4	*Betula alleghaniensis*
16	3	*Fagus grandifolia*
10	3	*Cornus florida*
5	3	*Ailanthus altissima**
1	3	*Amelanchier sp.*
0	3	*Populus grandidentata*
19	2	*Quercus rubra*
12	2	*Magnolia acuminata*
10	2	*Tilia americana*
5	2	*Quercus prinus*
5	2	*Vaccinium sp.*
2	2	*Fraxinus americana*
2	2	*Prunus pensylvanica*
0	2	*Acer negundo*
0	2	*Fraxinus sp.*
0	2	*Lonicera japonica**
0	2	*Oplopanax horridum*
0	2	*Paulownia tomentosa**
0	2	*Pinus rigida*
0	2	*Pinus virginiana*
7	1	*Cercis canadensis*
7	1	*Magnolia tripetala*
7	1	*Quercus alba*
7	1	*Sassafras albidum*
5	1	*Hydrangea arborescens*
4	1	*Quercus velutina*
2	1	*Fraxinus nigra*

Table 4 (con't)

Ranked by most to least common on forest sites.

Transect type	forest total	mined total
Number of transects	**23**	**25**
Species		
Prunus sp.	2	8
Prunus pensylvanica	2	2
Fraxinus americana	2	2
Fraxinus nigra	2	1
Vaccinium angustifolium	2	0
Castanea dentata	2	0
Azalea sp.	2	0
Platanus occidentalis	1	8
Rhus typhina	1	5
Amelanchier sp.	1	3
Rubus allegheniensis	1	1
Ulmus rubra	1	0
Tsuga canadensis	1	0
Rosa caroliniana	1	0
Rhododendron maximum	1	0
Quercus bicolor	1	0
Prunus virginiana	1	0
Morus sp.	1	0
Magnolia grandiflora	1	0
Kalmia latifolia	1	0
Aristolochia macrophylla	1	0
*Lespedeza bicolor**	0	6
*Alnus glutinosa**	0	5
Populus grandidentata	0	3
Pinus virginiana	0	2
Pinus rigida	0	2
*Paulownia tomentosa**	0	2
Oplopanax horridum	0	2
*Lonicera japonica**	0	2
Fraxinus sp.	0	2
Acer negundo	0	2
Rubus recurviculatus	0	1
Robinia hispida	0	1
Rhus glabra	0	1
Rhus copallinum	0	1
Quercus coccinea	0	1
Populus balsamifera	0	1
Pinus strobus	0	1
Pinus resinosa	0	1
Pinus echinata	0	1
Juniperus virginiana	0	1

Ranked by most to least common on mined sites.

forest total	mined total	Transect type
23	**25**	**Number of transects**
		Species
1	1	*Rubus allegheniensis*
0	1	*Juniperus virginiana*
0	1	*Pinus echinata*
0	1	*Pinus resinosa*
0	1	*Pinus strobus*
0	1	*Populus balsamifera*
0	1	*Quercus coccinea*
0	1	*Rhus copallinum*
0	1	*Rhus glabra*
0	1	*Robinia hispida*
0	1	*Rubus recurviculatus*
10	0	*Viburnum acerifolium*
9	0	*Acer pensylvanicum*
9	0	*Carpinus caroliniana*
9	0	*Carya cordiformis*
8	0	*Lindera benzoin*
7	0	*Hamamelis virginiana*
5	0	*Carya glabra*
5	0	*Ostrya virginiana*
4	0	*Aesculus octandra*
4	0	*Carya ovata*
4	0	*Carya tomentosa*
4	0	*Quercus marilandica*
3	0	*Carya sp.*
3	0	*Crataegus sp.*
3	0	*Magnolia fraseri*
3	0	*Magnolia soulangeana**
3	0	*Magnolia virginiana*
2	0	*Azalea sp.*
2	0	*Castanea dentata*
2	0	*Vaccinium angustifolium*
1	0	*Aristolochia macrophylla*
1	0	*Kalmia latifolia*
1	0	*Magnolia grandiflora*
1	0	*Morus sp.*
1	0	*Prunus virginiana*
1	0	*Quercus bicolor*
1	0	*Rhododendron maximum*
1	0	*Rosa caroliniana*
1	0	*Tsuga canadensis*
1	0	*Ulmus rubra*

Table 5: Woody species found at study sites by category. * denotes alien/non-native species

CF = Continuous forest MTR = Mountaintop removal BF = backfill
RF = Remnant forest VF = Valley fill CM = contour mine

	FOREST		MINED				FOREST	MINED
Transect type	**CF**	**RF**	**MTR**	**VF**	**BF**	**CM**	**TOTAL**	**TOTAL**
Number of transects	**5**	**20**	**4**	**16**	**5**	**5**	**25**	**30**
Species								
Acer negundo				2		1	0	3
Acer pensylvanicum		9					9	0
Acer rubrum	3	18	2	13	3	5	21	23
Acer saccharum	5	14		7	2		19	9
Aesculus octandra	3	1					4	0
*Ailanthus altissima**	3	2		3			5	3
*Alnus glutinosa**			2	3			0	5
Amelanchier sp.	1			2	1		1	3
Aristolochia macrophylla		1					1	0
Azalea sp.		2					2	0
Betula alleghaniensis	2	2		3	1		4	4
Betula lenta	1	12	1	6	2		13	9
Carpinus caroliniana	2	7					9	0
Carya cordiformis	3	6					9	0
Carya glabra	2	5				1	7	1
Carya ovata	2	2				1	4	1
Carya sp.	1	2				1	3	1
Carya tomentosa		4				1	4	1
Castanea dentata		2					2	0
Cercis canadensis	3	5		1			8	1
Cornus florida	5	6		3			11	3
Crataegus sp.		4					4	0
*Eleagnus umbellata**		2	2	11	2	4	2	19
Epigaea repens							0	0
Fagus grandifolia	4	13		3			17	3
Fraxinus americana		2		2		1	2	3
Fraxinus nigra		2		1			2	1
Fraxinus pennsylvanica	3	6	2	8		1	9	11
Fraxinus sp.				2			0	2
Hamamelis virginiana	2	5					7	0
Hydrangea arborescens	1	4		1			5	1
Juniperus virginiana				1			0	1
Kalmia latifolia		1					1	0
*Lespedeza bicolor**				6			0	6
Lindera benzoin	3	5					8	0
Liriodendron tulipifera	5	14	1	10	2	1	19	14
*Lonicera japonica**					2		0	2
Magnolia acuminata	5	9		2		3	14	5
Magnolia grandiflora	1						1	0
Magnolia fraseri		3					3	0
*Magnolia soulangeana**	1	2					3	0
Magnolia tripetala	2	5		1			7	1
Magnolia virginiana		3					3	0
Morus sp.		1					1	0
Oplopanax horridum				1	1		0	2
Ostrya virginiana		5					5	0

Table 5. (con't)

	FOREST		MINED				FOREST	MINED
Transect type	CF	RF	MTR	VF	BF	CM	TOTAL	TOTAL
Number of transects	5	20	4	16	5	5	25	30
Species								
Oxydendrum arboreum	1	8	2	9	2	5	9	18
Parthenocissus quinquefoli	5	11		7	1	4	16	12
*Paulownia tomentosa**				2			0	2
Pinus echinata				1			0	1
Pinus resinosa				1			0	1
Pinus rigida		1	1	1			1	2
Pinus strobus				1			0	1
Pinus virginiana		1		2		1	1	3
Platanus occidentalis		1		6	2	1	1	9
Populus balsamifera				1			0	1
Populus grandidentata			1	1	1		0	3
Prunus pensylvanica		2			2		2	2
Prunus serotina	2	6	1	4	1		8	6
Prunus sp.		2	1	5	2		2	8
Prunus virginiana		1					1	0
Quercus alba	2	6	1			2	8	3
Quercus bicolor		1					1	0
Quercus coccinea				1		1	0	2
Quercus marilandica	1	4				1	5	1
Quercus prinus	1	4		1	1		5	2
Quercus rubra	2	18		2		1	20	3
Quercus velutina		4		1		1	4	2
Rhododendron maximum		1					1	0
Rhus copallinum		2	1			2	2	3
Rhus glabra				1			0	1
Rhus typhina		1		5		1	1	6
Robinia hispida			1				0	1
Robinia pseudoacacia		7	3	12	4		7	19
Rosa caroliniana		1					1	0
*Rosa multiflora**		2	1	7		2	2	10
Rubus allegheniensis		1		1		2	1	3
Rubus recurviculatus				1			0	1
Rubus sp.	1	14	2	13	4	5	15	24
Sassafras albidum	1	8		1		2	9	3
Smilax glauca		1				1	1	1
Smilax sp.	5	14		4	1	2	19	7
Tilia americana	3	7		1	1		10	2
Toxicodendron radicans	4	10	2	7		2	14	11
Tsuga canadensis		1					1	0
Ulmus rubra	1						1	0
Vaccinium angustifolium		3				1	3	1
Vaccinium sp.	1	4			2	1	5	3
Viburnum acerifolium	3	7					10	0
Vitis sp.	1	9		5		1	10	6

Table 6. Woody species ranked by abundance in forested and mined sites. Contour mines excluded. (There were 33 forest transect points and 1601 mined points where no individual was found in range.)
* denotes alien/non-native species

Ranked by abundance on forested sites.

	Number of	
Species	**forest**	**mine**
Acer saccharum	206	24
Acer rubrum	127	221
Fagus grandifolia	70	4
Liriodendron tulipifera	68	62
Parthenocissus quinquefolia	58	8
Magnolia acuminata	51	1
Toxicodendron radicans	37	13
Quercus rubra	37	4
Oxydendrum arboreum	34	60
Smilax sp.	34	6
Acer pensylvanicum	33	0
Magnolia tripetala	31	1
Quercus prinus	30	1
Rubus sp.	28	187
Tilia americana	28	2
Betula lenta	27	19
Robinia pseudoacacia	25	217
Prunus serotina	22	17
Quercus alba	21	0
Sassafras albidum	20	4
Lindera benzoin	20	0
Fraxinus pennsylvanica	16	39
Vitis sp.	15	9
Fraxinus americana	14	6
Cornus florida	14	3
Aesculus octandra	14	0
Hamamelis virginiana	14	0
Vaccinium sp.	12	2
*Eleagnus umbellata**	11	106
*Ailanthus altissima**	11	4
Carya cordiformis	11	0
Carpinus caroliniana	10	0
Castanea dentata	10	0
Magnolia fraseri	10	0
Carya ovata	9	0
Viburnum acerifolium	9	0
Prunus sp.	8	17
Carya sp.	8	0
Prunus pensylvanica	7	4
Cercis canadensis	7	0
Carya glabra	5	0
Carya tomentosa	5	0
Hydrangea arborescens	5	0
Magnolia grandiflora	5	0
Ostrya virginiana	5	0
Quercus bicolor	5	0
Betula alleghaniensis	4	8
Quercus velutina	4	5
Fraxinus nigra	4	2

Ranked by abundance on mined sites.

Number of		
forest	**mine**	**Species**
127	221	*Acer rubrum*
25	217	*Robinia pseudoacacia*
28	187	*Rubus sp.*
11	106	*Eleagnus umbellata**
68	62	*Liriodendron tulipifera*
34	60	*Oxydendrum arboreum*
16	39	*Fraxinus pennsylvanica*
0	28	*Lespedeza bicolor**
1	26	*Rhus typhina*
206	24	*Acer saccharum*
27	19	*Betula lenta*
0	19	*Rosa multiflora**
22	17	*Prunus serotina*
8	17	*Prunus sp.*
1	14	*Platanus occidentalis*
37	13	*Toxicodendron radicans*
0	11	*Pinus strobus*
15	9	*Vitis sp.*
58	8	*Parthenocissus quinquefolia*
4	8	*Betula alleghaniensis*
0	7	*Pinus virginiana*
34	6	*Smilax sp.*
14	6	*Fraxinus americana*
4	5	*Quercus velutina*
0	5	*Pinus echinata*
0	5	*Rubus recurviculatus*
70	4	*Fagus grandifolia*
37	4	*Quercus rubra*
20	4	*Sassafras albidum*
11	4	*Ailanthus altissima**
7	4	*Prunus pensylvanica*
3	4	*Rubus allegheniensis*
0	4	*Fraxinus sp.*
0	4	*Oplopanax horridum*
14	3	*Cornus florida*
1	3	*Pinus rigida*
0	3	*Paulownia tomentosa**
28	2	*Tilia americana*
12	2	*Vaccinium sp.*
4	2	*Fraxinus nigra*
0	2	*Acer negundo*
0	2	*Amelanchier sp.*
0	2	*Juniperus virginiana*
0	2	*Populus balsamifera*
0	2	*Populus grandidentata*
0	2	*Rhus glabra*
51	1	*Magnolia acuminata*
31	1	*Magnolia tripetala*
30	1	*Quercus prinus*

Table 6. (con't)

Ranked by abundance on forested sites.

Species	Number of forest	Number of mine
*Magnolia soulangeana**	4	0
Magnolia virginiana	4	0
Rubus allegheniensis	3	4
Crataegus sp.	3	0
Quercus marilandica	3	0
Vaccinium angustifolium	3	0
Aesculus sp.	2	0
Hydrangea sp.	2	0
Prunus virginiana	2	0
Rhus typhina	1	26
Platanus occidentalis	1	14
Pinus rigida	1	3
Aristolochia macrophylla	1	0
Azalea sp.	1	0
Betula sp.	1	0
Kalmia latifolia	1	0
Magnolia sp.	1	0
Morus sp.	1	0
Rhus copallinum	1	0
Tsuga canadensis	1	0
Ulmus rubra	1	0
UNK- yellow fruit	1	0
UNK-w/photos	1	0
*Lespedeza bicolor**	0	28
*Rosa multiflora**	0	19
Pinus strobus	0	11
Pinus virginiana	0	7
Pinus echinata	0	5
Rubus recurviculatus	0	5
Fraxinus sp.	0	4
Oplopanax horridum	0	4
*Paulownia tomentosa**	0	3
Acer negundo	0	2
Amelanchier sp.	0	2
Juniperus virginiana	0	2
Populus balsamifera	0	2
Populus grandidentata	0	2
Rhus glabra	0	2
Amelanchier arborea	0	1
*Lonicera japonica*r**	0	1
Pinus resinosa	0	1
Quercus sp.	0	1
UNK-Amelanchier	0	1
UNK-shrub w/green-red berries	0	1
Total data points	**1299**	**1207**

Ranked by abundance on mined sites.

Number of forest	Number of mine	Species
0	1	*Amelanchier arborea*
0	1	*Lonicera japonica*r**
0	1	*Pinus resinosa*
0	1	*Quercus sp.*
0	1	UNK-Amelanchier
0	1	UNK-shrub w/green-red berries
33	0	*Acer pensylvanicum*
21	0	*Quercus alba*
20	0	*Lindera benzoin*
14	0	*Aesculus octandra*
14	0	*Hamamelis virginiana*
11	0	*Carya cordiformis*
10	0	*Carpinus caroliniana*
10	0	*Castanea dentata*
10	0	*Magnolia fraseri*
9	0	*Carya ovata*
9	0	*Viburnum acerifolium*
8	0	*Carya sp.*
7	0	*Cercis canadensis*
5	0	*Carya glabra*
5	0	*Carya tomentosa*
5	0	*Hydrangea arborescens*
5	0	*Magnolia grandiflora*
5	0	*Ostrya virginiana*
5	0	*Quercus bicolor*
4	0	*Magnolia soulangeana**
4	0	*Magnolia virginiana*
3	0	*Crataegus sp.*
3	0	*Quercus marilandica*
3	0	*Vaccinium angustifolium*
2	0	*Aesculus sp.*
2	0	*Hydrangea sp.*
2	0	*Prunus virginiana*
1	0	*Aristolochia macrophylla*
1	0	*Azalea sp.*
1	0	*Betula sp.*
1	0	*Kalmia latifolia*
1	0	*Magnolia sp.*
1	0	*Morus sp.*
1	0	*Rhus copallinum*
1	0	*Tsuga canadensis*
1	0	*Ulmus rubra*
1	0	UNK- yellow fruit
1	0	UNK-w/photos
1299	**1207**	**Total data points**

Table 7a: List of West Virginia herbaceous species found on transects sampled for the EIS terrestrial analyses (2000). (a indicates alien species)

	SCIENTIFIC NAME	COMMON NAME
	Actaea pachypoda	White baneberry
	Adiantum pedatum	Maidenhair fern
	Agrimonia striata	Woodland agrimony
	Allium tricoccum	Wild leek/ ramps
	Anemonella thalictroides	Rue anemone
	Antennaria plantaginifolia	Plantain pussytoes
	Arisaema triphyllum	Jack-in-the-pulpit
	Asarum canadense	Wild ginger
a	*Asparagus officinalis**	Wild asparagus
	Aster sp.	Aster sp.
	Botrychium sp.	Rattlesnake fern
	Carex blanda	Charming sedge
	Carex plantaginea	Plantain-like sedge
	Carex sp.	Sedge sp.
	Caulophyllum thalictroides	Blue cohosh
	Chimaphila maculata	Striped wintergreen
	Claytonia caroliniana	Spring beauty
	Delphinium tricorne	Dwarf larkspur
	Dentaria maxima	Large toothwort
	Dentaria multifida	Fine-leaved toothwort
	Dicentra cucullaria	Dutchman's breeches
	Dioscoria quaternata	Four-leaved wild yam
	Disporum languinosum	Fairy bells
	Epifagus virginiana	Beechdrops (epifagus)
	Erythronium americanum	Trout lily
	Fragaria virginiana	Strawberry
	Galium aparine	Cleavers
	Galium circaezans	Wild licorice
	Galium sp.	Galium sp.
	Galium tinctorum	Clayton's bedstraw
	Galium triflorum	Sweet scented bedstraw
	Geranium maculatum	Wild geranium
a	*Glechoma hederaea**	Gills-over-the-ground
	Goodyera repens	Dwarf rattlesnake plantain
	Hepatica acutiloba	Sharp-lobed hepatica
	Hydrophyllum macrophyllum	Broad-leaved waterleaf
	Impatiens capensis	Impatiens, Spotted touch-me-not
	Lactuca sp.	Wild lettuce
a	*Lamium purpureum**	Purple dead nettle
	Lycopus virginicus	Virginia bugleweed
	Medeola virginiana	Indian cucumber root
	Meehania cordata	Meehania
	Mitchella repens	Partridgeberry
	Osmorhiza claytonii	Hairy sweet Cicely
	Panax trifolium	Dwarf ginseng
	Pedicularis canadensis	Wood betony, lousewort
	Phlox sp.	Phlox
	Phlox stolonifera	Creeping phlox
	Podophyllum peltatum	Mayapple
	Polemonium reptans	Greek valerian (Jacob's ladder)
	Polygonatum biflorum	Smooth Solomon's seal
	Polygonum sp.	Polygonum sp.
	Polystichum acrostichoides	Christmas fern
	Potentilla canadensis	Dwarf cinquefoil

Table 7a. (con't)

	SCIENTIFIC NAME	COMMON NAME
	Potentilla sp.	Potentilla sp.
	Ranunculus sp.	Buttercup sp.
	Sanguinaria canadensis	Bloodroot
	Sedum ternatum	Wild stonecrop
	Senecio aureus	Golden ragwort
	Senecio obovatus	Round-leaved ragwort
	Silene virginica	Fire pink
	Smilacina racemosa	False Solomon's seal
	Smilax sp.	Catbrier
	Solidago sp.	Goldenrod
	Stellaria media	Common chickweed
a	*Stellaria pubera**	Star chickweed
	Tiarella cordifolia	Foamflower
	Trillium grandiflorum	Large-flowered trillium
a	*Tussilago farfara**	Coltsfoot
	Urtica dioica	Stinging nettle
	Vicia caroliniana	Wood vetch
	Viola blanda	Sweet white violet
	Viola canadensis	Stemmed white violet
	Viola macloskeyi (V. pallens)	Wild white violet
	Viola papilionacea	Common blue violet
	Viola pedata	Bird's-foot violet
	Viola pennsylvanica	Smooth yellow violet
	Viola rostrata	Long-spurred violet
	Viola rotundifolia	Round-leaved yellow violet
	Viola sp.	Violet sp.
	Viola striata	Creamy violet
	Waldsteinia fragarioides	Barren strawberry
	Zizia aurea	Golden Alexanders
		Grass sp.
		Mustard sp.

Observed in area, but not in data

	Carex sp.	Sedges
	Hieracium venosum	Rattlesnake weed
	Houstonia longifolia	Long-leaved Houstonia
	Iris cristata	Wild crested iris
	Mitella diphylla	Bishop's cap
	Obolaria virginica	Pennywort
	Phlox divaricata	Wild blue phlox
	Ranunculus recurvatus	Hooked crowfoot
	Ranunculus sceleratus	Cursed crowfoot
	Smilax herbacea	Carrion flower
a	*Stellaria aquatica*	Giant chickweed
a	*Stellaria holostea**	Easter bell
	Zizia aptera	Heart-leaved Alexanders

Table 7b. List of West Virginia spring herbaceous species observed on three valley fills. * indicates alien/non-native species.

Alliaria petiolata*	Garlic mustard
Asarum canadense	Wild ginger
Aster sp.	Aster species
Brassicaceae	Mustard species
*Coronilla varia**	Crown vetch
Galium aparine	Cleavers
Galium tinctorum	Clayton's bedstraw
Grass sp.	Grass species
*Lamium purpureum**	Purple dead nettle
*Lespedeza bicolor**	Bush clover
Phlox sp.	Phlox species
Polygonum sp.	Polygonum species
Polystichum acrostichoides	Christmas fern
Potentilla canadensis	Dwarf cinquefoil
Ranunculus sp.	Buttercup species
Silene virginica	Fire pink
Stellaria pubera	Star chickweed
*Trifolium sp.**	Clover species
*Tussilago farfara**	Coltsfoot
Unk.	Dandelion-like milky weed
Vicia caroliniana	Wood vetch
Viola sp.	Violet species
Waldsteinia fragarioides	Barren strawberry
Zizia aurea	Golden Alexanders

Table 8. Herbaceous species found on study sites, ranked from most to least present.
indicates alien/non-native species

Ranked by most to least common in intact forest sites.

Species	intact forest (11 sites)	engineered (5 sites)
*Stellaria pubera**	11	4
Anemonella thalictroides	11	1
Polygonum sp.	10	4
Viola sp.	10	4
Tiarella cordifolia	10	2
Smilacina racemosa	10	1
Aster sp.	9	4
Geranium maculatum	9	3
Lactuca sp.	9	3
Sedum ternatum	9	3
Osmorhiza claytonii	9	1
Arisaema triphyllum	8	3
Podophyllum peltatum	8	3
Polygonatum biflorum	8	1
Polystichum acrostichoides	7	3
Trillium grandiflorum	7	2
Fragaria virginiana	6	3
Asarum canadense	6	2
Botrychium sp.	6	1
Dentaria multifida	6	1
Erythronium americanum	6	1
Galium circaezans	5	2
Sanguinaria canadensis	5	2
Actaea pachypoda	5	1
Disporum languinosum	5	1
Hydrophyllum macrophyllum	5	1
Galium triflorum	4	2
Claytonia caroliniana	4	1
Medeola virginiana	4	1
Mitchella repens	4	1
Urtica dioica	4	1
Caulophyllum thalictroides	4	0
Chimaphila maculata	4	0
Dicentra cucullaria	4	0
Hepatica acutiloba	4	0
Viola rostrata	3	4
Dioscoria quaternata	3	3
Galium aparine	3	2
Potentilla canadensis	3	2
Viola papilionacea	3	2
*Glechoma hederaea**	3	1
Impatiens capensis	3	1
Viola blanda	3	0
Viola pennsylvanica	3	0
Delphinium tricorne	2	2
Viola rotundifolia	2	2
Carex plantaginea	2	0
Dentaria maxima	2	0
Meehania cordata	2	0
Carex sp.	1	4
Viola canadensis	1	2
Galium sp.	1	1
Goodyera repens	1	1
Pedicularis canadensis	1	1
Phlox sp.	1	1
Polemonium reptans	1	1
Smilax sp.	1	1
Solidago sp.	1	1

Ranked by most to least common in engineered sites.

intact forest (11 sites)	engineered (5 sites)	Species
11	4	*Stellaria pubera**
10	4	*Polygonum sp.*
10	4	*Viola sp.*
9	4	*Aster sp.*
3	4	*Viola rostrata*
1	4	*Carex sp.*
9	3	*Geranium maculatum*
9	3	*Lactuca sp.*
9	3	*Sedum ternatum*
8	3	*Arisaema triphyllum*
8	3	*Podophyllum peltatum*
7	3	*Polystichum acrostichoides*
6	3	*Fragaria virginiana*
3	3	*Dioscoria quaternata*
10	2	*Tiarella cordifolia*
7	2	*Trillium grandiflorum*
6	2	*Asarum canadense*
5	2	*Galium circaezans*
5	2	*Sanguinaria canadensis*
4	2	*Galium triflorum*
3	2	*Galium aparine*
3	2	*Potentilla canadensis*
3	2	*Viola papilionacea*
2	2	*Delphinium tricorne*
2	2	*Viola rotundifolia*
1	2	*Viola canadensis*
0	2	*Agrimonia striata*
0	2	*Senecio aureus*
11	1	*Anemonella thalictroides*
10	1	*Smilacina racemosa*
9	1	*Osmorhiza claytonii*
8	1	*Polygonatum biflorum*
6	1	*Botrychium sp.*
6	1	*Dentaria multifida*
6	1	*Erythronium americanum*
5	1	*Actaea pachypoda*
5	1	*Disporum languinosum*
5	1	*Hydrophyllum macrophyllum*
4	1	*Claytonia caroliniana*
4	1	*Medeola virginiana*
4	1	*Mitchella repens*
4	1	*Urtica dioica*
3	1	*Glechoma hederaea**
3	1	*Impatiens capensis*
1	1	*Galium sp.*
1	1	*Goodyera repens*
1	1	*Pedicularis canadensis*
1	1	*Phlox sp.*
1	1	*Polemonium reptans*
1	1	*Smilax sp.*
1	1	*Solidago sp.*
1	1	*Zizia aurea*
1	1	Unk composite
0	1	*Antennaria plantaginifolia*
0	1	*Carex blanda*
0	1	*Ranunculus sp.*
0	1	*Senecio obovatus*
0	1	*Stellaria media*

Table 8. (con't)

Ranked by most to least common in intact forest sites.

Species	intact forest (11 sites)	engineered (5 sites)
Zizia aurea	1	1
Unk composite	1	1
Adiantum pedatum	1	0
Allium tricoccum	1	0
*Asparagus officinalis**	1	0
Epifagus virginiana	1	0
Lycopus virginicus	1	0
Panax trifolium	1	0
Phlox stolonifera	1	0
Potentilla sp.	1	0
Viola macloskeyi (V. pallens)	1	0
Waldsteinia fragarioides	1	0
Carex, narrow	1	0
Carex, pale & broad	1	0
Unk -- very hirsute	1	0
Unk -- round leaf	1	0
Unk- 3 mitten leaf	1	0
Unk 3-3 leaf	1	0
Unk fern	1	0
Unk -geranium like	1	0
Unk ground cover	1	0
Unk - purple flower "rue"	1	0
low 3-leave	1	0
Agrimonia striata	0	2
Senecio aureus	0	2
Antennaria plantaginifolia	0	1
Carex blanda	0	1
Ranunculus sp.	0	1
Senecio obovatus	0	1
Stellaria media	0	1
Viola pedata	0	1
Viola striata	0	1
Unk - tomentose	0	1
Unk 6 thin-leaved galium	0	1
Unk ground cover, purple	0	1
Unk heart leaf herb	0	1

Ranked by most to least common in engineered sites.

intact forest (11 sites)	engineered (5 sites)	Species
0	1	*Viola pedata*
0	1	*Viola striata*
0	1	Unk - tomentose
0	1	Unk 6 thin-leaved galium
0	1	Unk ground cover, purple
0	1	Unk heart leaf herb
4	0	*Caulophyllum thalictroides*
4	0	*Chimaphila maculata*
4	0	*Dicentra cucullaria*
4	0	*Hepatica acutiloba*
3	0	*Viola blanda*
3	0	*Viola pennsylvanica*
2	0	*Carex plantaginea*
2	0	*Dentaria maxima*
2	0	*Meehania cordata*
1	0	*Adiantum pedatum*
1	0	*Allium tricoccum*
1	0	*Asparagus officinalis**
1	0	*Epifagus virginiana*
1	0	*Lycopus virginicus*
1	0	*Panax trifolium*
1	0	*Phlox stolonifera*
1	0	*Potentilla sp.*
1	0	*Viola macloskeyi (V. pallens)*
1	0	*Waldsteinia fragarioides*
1	0	*Carex*, narrow
1	0	*Carex*, plae & broad
1	0	Unk -- very hirsute
1	0	Unk -- round leaf
1	0	Unk- 3 mitten leaf
1	0	Unk 3-3 leaf
1	0	Unk fern
1	0	Unk -geranium like
1	0	Unk ground cover
1	0	Unk -purple flower "rue"
1	0	low 3-leave

Table 9a. Herbaceous species found at study sites, ranked from most to least abundant (number of stems counted) in engineered and intact forests. * indicates alien/non-native species

Ranked by abundance in intact study sites.

Species	intact (8897 stems)	engineered (1840 stems)
Sedum ternatum	1043	180
Tiarella cordifolia	872	82
Dicentra cucullaria	702	0
Aster sp.	377	92
Urtica dioica	305	1
Fragaria virginiana	292	17
Osmorhiza claytonii	292	9
Erythronium americanum	279	7
Dentaria maxima	270	0
Viola sp.	256	70
Meehania cordata	245	0
*Stellaria pubera**	241	94
Botrychium sp.	236	7
Asarum canadense	215	71
Polygonum sp.	192	113
Podophyllum peltatum	182	60
Arisaema triphyllum	179	41
Polystichum acrostichoides	172	25
Anemonella thalictroides	171	35
*Glechoma hederaea**	149	19
Claytonia caroliniana	143	1
Geranium maculatum	139	51
Trillium grandiflorum	136	18
Lactuca sp.	107	64
Smilacina racemosa	99	1
Delphinium tricorne	94	71
Impatiens capensis	92	10
Viola blanda	89	0
Galium aparine	85	35
Dentaria multifida	77	1
Hydrophyllum macrophyllum	76	10
Medeola virginiana	75	13
Caulophyllum thalictroides	73	0
Hepatica acutiloba	65	0
Polygonatum biflorum	57	6
Viola rostrata	52	60
Lycopus virginicus	50	0
low 3-leave	50	0
Galium sp.	47	29
Mitchella repens	38	6
Unk 3-3 leaf	38	0
Panax trifolium	36	0
Sanguinaria canadensis	35	6
Galium triflorum	27	5
Actaea pachypoda	26	1
Phlox stolonifera	26	0
Dioscoria quaternata	24	9
Galium circaezans	23	55
Viola papilionacea	23	28
Disporum languinosum	23	14
Allium tricoccum	21	0
Polemonium reptans	18	91
Carex plantaginea	17	0
Carex, narrow	17	0
Potentilla canadensis	16	36
Viola canadensis	16	12

Ranked by abundance in engineered study sites.

intact (8897 stems)	engineered (1840 stems)	Species
1043	180	*Sedum ternatum*
192	113	*Polygonum sp.*
241	94	*Stellaria pubera**
377	92	*Aster sp.*
18	91	*Polemonium reptans*
872	82	*Tiarella cordifolia*
0	73	*Senecio aureus*
215	71	*Asarum canadense*
94	71	*Delphinium tricorne*
256	70	*Viola sp.*
107	64	*Lactuca sp.*
182	60	*Podophyllum peltatum*
52	60	*Viola rostrata*
23	55	*Galium circaezans*
139	51	*Geranium maculatum*
179	41	*Arisaema triphyllum*
3	38	*Phlox sp.*
16	36	*Potentilla canadensis*
171	35	*Anemonella thalictroides*
85	35	*Galium aparine*
47	29	*Galium sp.*
23	28	*Viola papilionacea*
12	26	*Pedicularis canadensis*
172	25	*Polystichum acrostichoides*
149	19	*Glechoma hederaea**
136	18	*Trillium grandiflorum*
292	17	*Fragaria virginiana*
5	15	*Carex sp.*
23	14	*Disporum languinosum*
75	13	*Medeola virginiana*
3	13	*Smilax sp.*
0	13	*Viola pedata*
16	12	*Viola canadensis*
8	11	*Viola rotundifolia*
0	11	*Agrimonia striata*
92	10	*Impatiens capensis*
76	10	*Hydrophyllum macrophyllum*
2	10	*Goodyera repens*
0	10	Unk ground cover, purple
292	9	*Osmorhiza claytonii*
24	9	*Dioscoria quaternata*
279	7	*Erythronium americanum*
236	7	*Botrychium sp.*
57	6	*Polygonatum biflorum*
38	6	*Mitchella repens*
35	6	*Sanguinaria canadensis*
0	6	Unk heart leaf herb
27	5	*Galium triflorum*
0	5	*Antennaria plantaginifolia*
0	5	*Carex blanda*
0	5	*Senecio obovatus*
0	3	Unk 6 thin-leaved galium
0	2	*Viola striata*
305	1	*Urtica dioica*
143	1	*Claytonia caroliniana*
99	1	*Smilacina racemosa*

Table 9a. (con't)

Ranked by abundance in intact study sites.

Species	intact (8897 stems)	engineered (1840 stems)
Pedicularis canadensis	12	26
Unk composite	12	1
Chimaphila maculata	12	0
Viola macloskeyi (V. pallens)	11	0
Viola pennsylvanica	11	0
Viola rotundifolia	8	11
Carex, pale & broad	6	0
Carex sp.	5	15
Adiantum pedatum	5	0
Unk -geranium like	4	0
Phlox sp.	3	38
Smilax sp.	3	13
Potentilla sp.	3	0
Unk- 3 mitten leaf	3	0
Unk fern	3	0
Unk- purple flower "rue"	3	0
Goodyera repens	2	10
Zizia aurea	2	1
Epifagus virginiana	2	0
Waldsteinia fragarioides	2	0
Solidago sp.	1	1
*Asparagus officinalis**	1	0
Unk -- very hirsute	1	0
Unk -- round leaf	1	0
Unk ground cover	1	0
Senecio aureus	0	73
Viola pedata	0	13
Agrimonia striata	0	11
Unk ground cover, purple	0	10
Unk heart leaf herb	0	6
Antennaria plantaginifolia	0	5
Carex blanda	0	5
Senecio obovatus	0	5
Unk 6 thin-leaved galium	0	3
Viola striata	0	2
Ranunculus sp.	0	1
Stellaria media	0	1
Unk - tomentose	0	1

Ranked by abundance in engineered study sites.

intact (8897 stems)	engineered (1840 stems)	Species
77	1	*Dentaria multifida*
26	1	*Actaea pachypoda*
12	1	Unk composite
2	1	*Zizia aurea*
1	1	*Solidago sp.*
0	1	*Ranunculus sp.*
0	1	*Stellaria media*
0	1	Unk - tomentose
702	0	*Dicentra cucullaria*
270	0	*Dentaria maxima*
245	0	*Meehania cordata*
89	0	*Viola blanda*
73	0	*Caulophyllum thalictroides*
65	0	*Hepatica acutiloba*
50	0	*Lycopus virginicus*
50	0	low 3-leave
38	0	Unk 3-3 leaf
36	0	*Panax trifolium*
26	0	*Phlox stolonifera*
21	0	*Allium tricoccum*
17	0	*Carex plantaginea*
17	0	*Carex*, narrow
12	0	*Chimaphila maculata*
11	0	*Viola macloskeyi (V. pallens)*
11	0	*Viola pennsylvanica*
6	0	*Carex*, pale & broad
5	0	*Adiantum pedatum*
4	0	Unk -geranium like
3	0	*Potentilla sp.*
3	0	Unk- 3 mitten leaf
3	0	Unk fern
3	0	Unk- purple flower "rue"
2	0	*Epifagus virginiana*
2	0	*Waldsteinia fragarioides*
1	0	*Asparagus officinalis**
1	0	Unk -- very hirsute
1	0	Unk -- round leaf
1	0	Unk ground cover

Table 9b. Herbaceous species found at study sites, ranked by percent abundance (number of stems counted) in engineered and intact forests. * indicates

Ranked by percent abundance on intact study sites.

Species	intact (of 8897)	engineered (of 1840)
Sedum ternatum	11.7	9.8
Tiarella cordifolia	9.8	4.5
Dicentra cucullaria	7.9	0.0
Aster sp.	4.2	5.0
Urtica dioica	3.4	0.1
Fragaria virginiana	3.3	0.9
Osmorhiza claytonii	3.3	0.5
Erythronium americanum	3.1	0.4
Dentaria maxima	3.0	0.0
Viola sp.	2.9	3.8
Meehania cordata	2.8	0.0
*Stellaria pubera**	2.7	5.1
Botrychium sp.	2.7	0.4
Asarum canadense	2.4	3.9
Polygonum sp.	2.2	6.1
Podophyllum peltatum	2.0	3.3
Arisaema triphyllum	2.0	2.2
Polystichum acrostichoides	1.9	1.4
Anemonella thalictroides	1.9	1.9
*Glechoma hederaea**	1.7	1.0
Claytonia caroliniana	1.6	0.1
Geranium maculatum	1.6	2.8
Trillium grandiflorum	1.5	1.0
Lactuca sp.	1.2	3.5
Smilacina racemosa	1.1	0.1
Delphinium tricorne	1.1	3.9
Impatiens capensis	1.0	0.5
Viola blanda	1.0	0.0
Galium aparine	1.0	1.9
Dentaria multifida	0.9	0.1
Hydrophyllum macrophyllum	0.9	0.5
Medeola virginiana	0.8	0.7
Caulophyllum thalictroides	0.8	0.0
Hepatica acutiloba	0.7	0.0
Polygonatum biflorum	0.6	0.3
Viola rostrata	0.6	3.3
Lycopus virginicus	0.6	0.0
low 3-leave	0.6	0.0
Galium sp.	0.5	1.6
Mitchella repens	0.4	0.3
Unk 3-3 leaf	0.4	0.0
Panax trifolium	0.4	0.0
Sanguinaria canadensis	0.4	0.3
Galium triflorum	0.3	0.3
Actaea pachypoda	0.3	0.1
Phlox stolonifera	0.3	0.0
Dioscoria quaternata	0.3	0.5
Galium circaezans	0.3	3.0
Viola papilionacea	0.3	1.5
Disporum languinosum	0.3	0.8
Allium tricoccum	0.2	0.0
Polemonium reptans	0.2	4.9
Carex plantaginea	0.2	0.0
Carex, narrow	0.2	0.0
Potentilla canadensis	0.2	2.0
Viola canadensis	0.2	0.7
Pedicularis canadensis	0.1	1.4

Ranked by percent abundance on engineered sites.

intact (of 8897)	engineered (of 1840)	Species
11.7	9.8	*Sedum ternatum*
2.2	6.1	*Polygonum sp.*
2.7	5.1	*Stellaria pubera**
4.2	5.0	*Aster sp.*
0.2	4.9	*Polemonium reptans*
9.8	4.5	*Tiarella cordifolia*
0.0	4.0	*Senecio aureus*
2.4	3.9	*Asarum canadense*
1.1	3.9	*Delphinium tricorne*
2.9	3.8	*Viola sp.*
1.2	3.5	*Lactuca sp.*
2.0	3.3	*Podophyllum peltatum*
0.6	3.3	*Viola rostrata*
0.3	3.0	*Galium circaezans*
1.6	2.8	*Geranium maculatum*
2.0	2.2	*Arisaema triphyllum*
0.0	2.1	*Phlox sp.*
0.2	2.0	*Potentilla canadensis*
1.9	1.9	*Anemonella thalictroides*
1.0	1.9	*Galium aparine*
0.5	1.6	*Galium sp.*
0.3	1.5	*Viola papilionacea*
0.1	1.4	*Pedicularis canadensis*
1.9	1.4	*Polystichum acrostichoides*
1.7	1.0	*Glechoma hederaea**
1.5	1.0	*Trillium grandiflorum*
3.3	0.9	*Fragaria virginiana*
0.1	0.8	*Carex sp.*
0.3	0.8	*Disporum languinosum*
0.8	0.7	*Medeola virginiana*
0.0	0.7	*Smilax sp.*
0.0	0.7	*Viola pedata*
0.2	0.7	*Viola canadensis*
0.1	0.6	*Viola rotundifolia*
0.0	0.6	*Agrimonia striata*
1.0	0.5	*Impatiens capensis*
0.9	0.5	*Hydrophyllum macrophyllum*
0.0	0.5	*Goodyera repens*
0.0	0.5	Unk ground cover, purple
3.3	0.5	*Osmorhiza claytonii*
0.3	0.5	*Dioscoria quaternata*
3.1	0.4	*Erythronium americanum*
2.7	0.4	*Botrychium sp.*
0.6	0.3	*Polygonatum biflorum*
0.4	0.3	*Mitchella repens*
0.4	0.3	*Sanguinaria canadensis*
0.0	0.3	Unk heart leaf herb
0.3	0.3	*Galium triflorum*
0.0	0.3	*Antennaria plantaginifolia*
0.0	0.3	*Carex blanda*
0.0	0.3	*Senecio obovatus*
0.0	0.2	Unk 6 thin-leaved galium
0.0	0.1	*Viola striata*
3.4	0.1	*Urtica dioica*
1.6	0.1	*Claytonia caroliniana*
1.1	0.1	*Smilacina racemosa*
0.9	0.1	*Dentaria multifida*

Table 9b. (con't)

Ranked by percent abundance on intact study sites.

	intact	engineered
Species	**(of 8897)**	**(of 1840)**
Unk composite	0.1	0.1
Chimaphila maculata	0.1	0.0
Viola macloskeyi (V. pallens)	0.1	0.0
Viola pennsylvanica	0.1	0.0
Viola rotundifolia	0.1	0.6
Carex, pale & broad	0.1	0.0
Carex sp.	0.1	0.8
Adiantum pedatum	0.1	0.0
Unk -geranium like	0.0	0.0
Phlox sp.	0.0	2.1
Smilax sp.	0.0	0.7
Potentilla sp.	0.0	0.0
Unk- 3 mitten leaf	0.0	0.0
Unk fern	0.0	0.0
Unk - purple flower "rue"	0.0	0.0
Goodyera repens	0.0	0.5
Zizia aurea	0.0	0.1
Epifagus virginiana	0.0	0.0
Waldsteinia fragarioides	0.0	0.0
Solidago sp.	0.0	0.1
*Asparagus officinalis**	0.0	0.0
Unk -- very hirsute	0.0	0.0
Unk -- round leaf	0.0	0.0
Unk ground cover	0.0	0.0
Senecio aureus	0.0	4.0
Viola pedata	0.0	0.7
Agrimonia striata	0.0	0.6
Unk ground cover, purple	0.0	0.5
Unk heart leaf herb	0.0	0.3
Antennaria plantaginifolia	0.0	0.3
Carex blanda	0.0	0.3
Senecio obovatus	0.0	0.3
Unk 6 thin-leaved galium	0.0	0.2
Viola striata	0.0	0.1
Ranunculus sp.	0.0	0.1
Stellaria media	0.0	0.1
Unk - tomentose	0.0	0.1

Ranked by percent abundance on engineered sites.

intact	engineered	
(of 8897)	**(of 1840)**	**Species**
0.3	0.1	*Actaea pachypoda*
0.1	0.1	Unk composite
0.0	0.1	*Zizia aurea*
0.0	0.1	*Solidago sp.*
0.0	0.1	*Ranunculus sp.*
0.0	0.1	*Stellaria media*
0.0	0.1	Unk - tomentose
7.9	0.0	*Dicentra cucullaria*
3.0	0.0	*Dentaria maxima*
2.8	0.0	*Meehania cordata*
1.0	0.0	*Viola blanda*
0.8	0.0	*Caulophyllum thalictroides*
0.7	0.0	*Hepatica acutiloba*
0.6	0.0	*Lycopus virginicus*
0.6	0.0	low 3-leave
0.4	0.0	Unk 3-3 leaf
0.4	0.0	*Panax trifolium*
0.3	0.0	*Phlox stolonifera*
0.2	0.0	*Allium tricoccum*
0.2	0.0	*Carex plantaginea*
0.2	0.0	*Carex, narrow*
0.1	0.0	*Chimaphila maculata*
0.1	0.0	*Viola macloskeyi (V. pallens)*
0.1	0.0	*Viola pennsylvanica*
0.1	0.0	*Carex, pale & broad*
0.1	0.0	*Adiantum pedatum*
0.0	0.0	Unk -geranium like
0.0	0.0	*Potentilla sp.*
0.0	0.0	Unk- 3 mitten leaf
0.0	0.0	Unk fern
0.0	0.0	Unk - purple flower "rue"
0.0	0.0	*Epifagus virginiana*
0.0	0.0	*Waldsteinia fragarioides*
0.0	0.0	*Asparagus officinalis**
0.0	0.0	Unk -- very hirsute
0.0	0.0	Unk -- round leaf
0.0	0.0	Unk ground cover

Table 10. Herbaceous species found at study sites, ranked by abundance (number of stems) in engineered and intact sites. (Values have been standardized by multiplying engineered numbers by 11/5 to even out difference in number of sites sampled.)
* indicates alien/non-native species

Ranked by abundance on intact sites.

Species	intact	engineered
Sedum ternatum	1043	396
Tiarella cordifolia	872	180
Dicentra cucullaria	702	0
Aster sp.	377	202
Urtica dioica	305	2
Fragaria virginiana	292	37
Osmorhiza claytonii	292	20
Erythronium americanum	279	15
Dentaria maxima	270	0
Viola sp.	256	154
Meehania cordata	245	0
*Stellaria pubera**	241	207
Botrychium sp.	236	15
Asarum canadense	215	156
Polygonum sp.	192	249
Podophyllum peltatum	182	132
Arisaema triphyllum	179	90
Polystichum acrostichoides	172	55
Anemonella thalictroides	171	77
*Glechoma hederaea**	149	42
Claytonia caroliniana	143	2
Geranium maculatum	139	112
Trillium grandiflorum	136	40
Lactuca sp.	107	141
Smilacina racemosa	99	2
Delphinium tricorne	94	156
Impatiens capensis	92	22
Viola blanda	89	0
Galium aparine	85	77
Dentaria multifida	77	2
Hydrophyllum macrophyllum	76	22
Medeola virginiana	75	29
Caulophyllum thalictroides	73	0
Hepatica acutiloba	65	0
Polygonatum biflorum	57	13
Viola rostrata	52	132
Lycopus virginicus	50	0
low 3-leaves	50	0
Galium sp.	47	64
Mitchella repens	38	13
3-3 leaf	38	0
Panax trifolium	36	0
Sanguinaria canadensis	35	13
Galium triflorum	27	11
Actaea pachypoda	26	2
Phlox stolonifera	26	0
Dioscoria quaternata	24	20
Galium circaezans	23	121
Viola papilionacea	23	62
Disporum languinosum	23	31
Allium tricoccum	21	0
Polemonium reptans	18	200
Carex plantaginea	17	0
Carex, narrow	17	0
Potentilla canadensis	16	79
Viola canadensis	16	26
Pedicularis canadensis	12	57
Unk composite	12	2
Chimaphila maculata	12	0
Viola macloskeyi (V. pallens)	11	0

Ranked by abundance on engineered sites.

intact	engineered	Species
1043	396	*Sedum ternatum*
872	249	*Polygonum sp.*
702	207	*Stellaria pubera**
377	202	*Aster sp.*
305	200	*Polemonium reptans*
292	180	*Tiarella cordifolia*
292	161	*Senecio aureus*
279	156	*Asarum canadense*
270	156	*Delphinium tricorne*
256	154	*Viola sp.*
245	141	*Lactuca sp.*
241	132	*Podophyllum peltatum*
236	132	*Viola rostrata*
215	121	*Galium circaezans*
192	112	*Geranium maculatum*
182	90	*Arisaema triphyllum*
179	84	*Phlox sp.*
172	79	*Potentilla canadensis*
171	77	*Anemonella thalictroides*
149	77	*Galium aparine*
143	64	*Galium sp.*
139	62	*Viola papilionacea*
136	57	*Pedicularis canadensis*
107	55	*Polystichum acrostichoides*
99	42	*Glechoma hederaea**
94	40	*Trillium grandiflorum*
92	37	*Fragaria virginiana*
89	33	*Carex sp.*
85	31	*Disporum languinosum*
77	29	*Medeola virginiana*
76	29	*Smilax sp.*
75	29	*Viola pedata*
73	26	*Viola canadensis*
65	24	*Viola rotundifolia*
57	24	*Agrimonia striata*
52	22	*Impatiens capensis*
50	22	*Hydrophyllum macrophyllum*
50	22	*Goodyera repens*
47	22	Unk ground cover, purple
38	20	*Osmorhiza claytonii*
38	20	*Dioscoria quaternata*
36	15	*Erythronium americanum*
35	15	*Botrychium sp.*
27	13	*Polygonatum biflorum*
26	13	*Mitchella repens*
26	13	*Sanguinaria canadensis*
24	13	heart leaf herb
23	11	*Galium triflorum*
23	11	*Antennaria plantaginifolia*
23	11	*Carex blanda*
21	11	*Senecio obovatus*
18	7	6 thin-leaved galium
17	4	*Viola striata*
17	2	*Urtica dioica*
16	2	*Claytonia caroliniana*
16	2	*Smilacina racemosa*
12	2	*Dentaria multifida*
12	2	*Actaea pachypoda*
12	2	Unk composite
11	2	*Zizia aurea*

Table 10 (con't)

Ranked by abundance on intact sites.

Species	intact	engineered
Viola pennsylvanica	11	0
Viola rotundifolia	8	24
Sedge 2 (pale, broad)	6	0
Carex sp.	5	33
Adiantum pedatum	5	0
Unk -geranium like	4	0
Phlox sp.	3	84
Smilax sp.	3	29
Potentilla sp.	3	0
Unk- 3 mitten leaf	3	0
Unk fern	3	0
Unk - purple flower "rue"	3	0
Goodyera repens	2	22
Zizia aurea	2	2
Epifagus virginiana	2	0
Waldsteinia fragarioides	2	0
Solidago sp.	1	2
*Asparagus officinalis**	1	0
Unk -- very hirsute	1	0
Unk -- round leaf	1	0
Unk ground cover	1	0
Senecio aureus	0	161
Viola pedata	0	29
Agrimonia striata	0	24
Unk ground cover, purple	0	22
heart leaf herb	0	13
Antennaria plantaginifolia	0	11
Carex blanda	0	11
Senecio obovatus	0	11
Unk 6 thin-leaved galium	0	7
Viola striata	0	4
Ranunculus sp.	0	2
Stellaria media	0	2
Unk - tomentose	0	2

Ranked by abundance on engineered sites.

intact	engineered	Species
11	2	*Solidago sp.*
8	2	*Ranunculus sp.*
6	2	*Stellaria media*
5	2	Unk - tomentose
5	0	*Dicentra cucullaria*
4	0	*Dentaria maxima*
3	0	*Meehania cordata*
3	0	*Viola blanda*
3	0	*Caulophyllum thalictroides*
3	0	*Hepatica acutiloba*
3	0	*Lycopus virginicus*
3	0	low 3-leave
2	0	3-3 leaf
2	0	*Panax trifolium*
2	0	*Phlox stolonifera*
2	0	*Allium tricoccum*
1	0	*Carex plantaginea*
1	0	*Carex*, narrow
1	0	*Chimaphila maculata*
1	0	*Viola macloskeyi (V. pallens)*
1	0	*Viola pennsylvanica*
0	0	Sedge 2 (pale, broad)
0	0	*Adiantum pedatum*
0	0	Unk -geranium like
0	0	*Potentilla sp.*
0	0	Unk- 3 mitten leaf
0	0	Unk fern
0	0	Unk- purple flower "rue"
0	0	*Epifagus virginiana*
0	0	*Waldsteinia fragarioides*
0	0	*Asparagus officinalis**
0	0	Unk -- very hirsute
0	0	Unk -- round leaf
0	0	Unk ground cover

Fulk 2003 Study
Final Version
with Pagination

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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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 objectives 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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ACKNOWLEDGMENTS

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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 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).

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.

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 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).

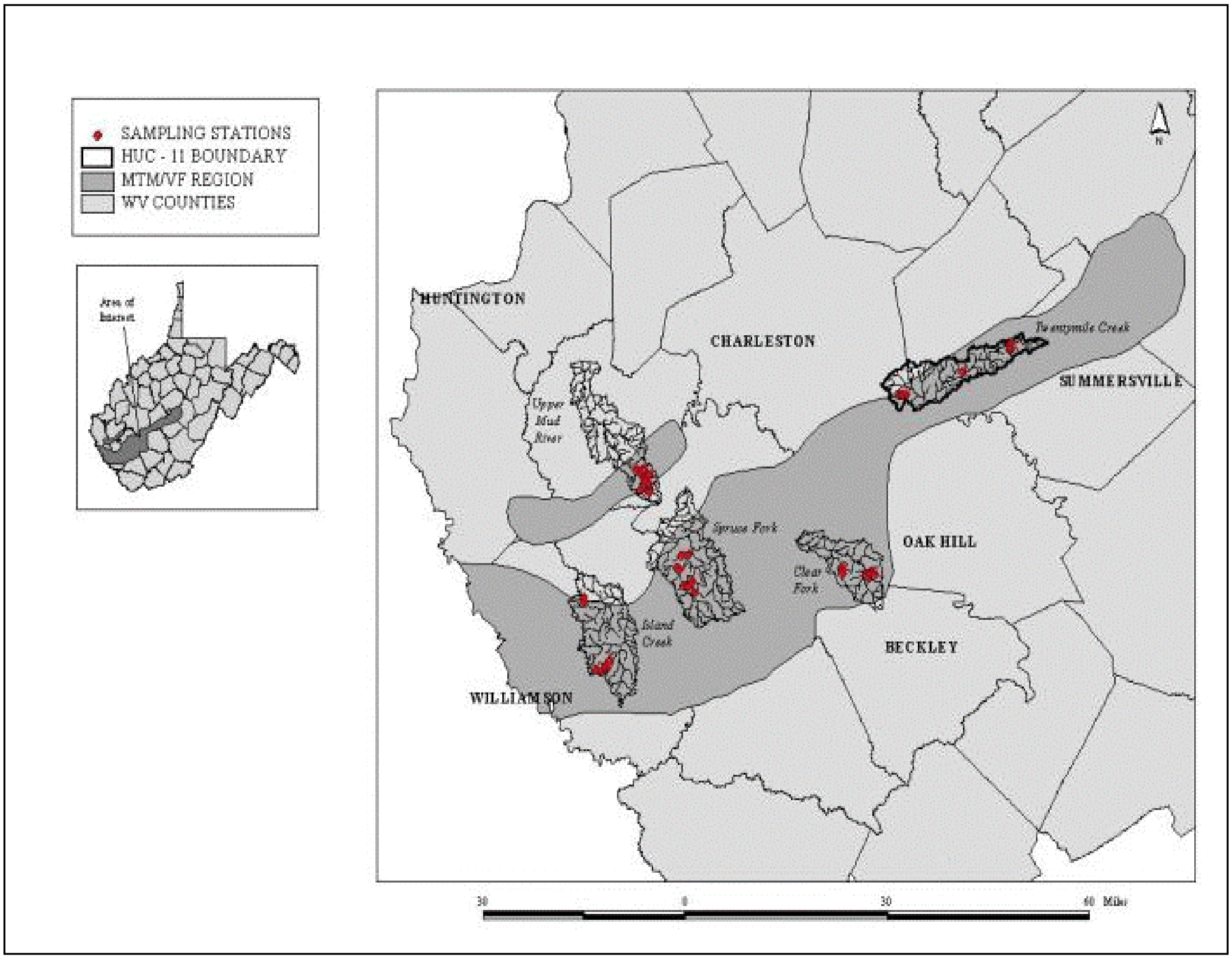


Figure 2-1. Study area for the aquatic impacts study of the MTM/VF Region of West Virginia.

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 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).

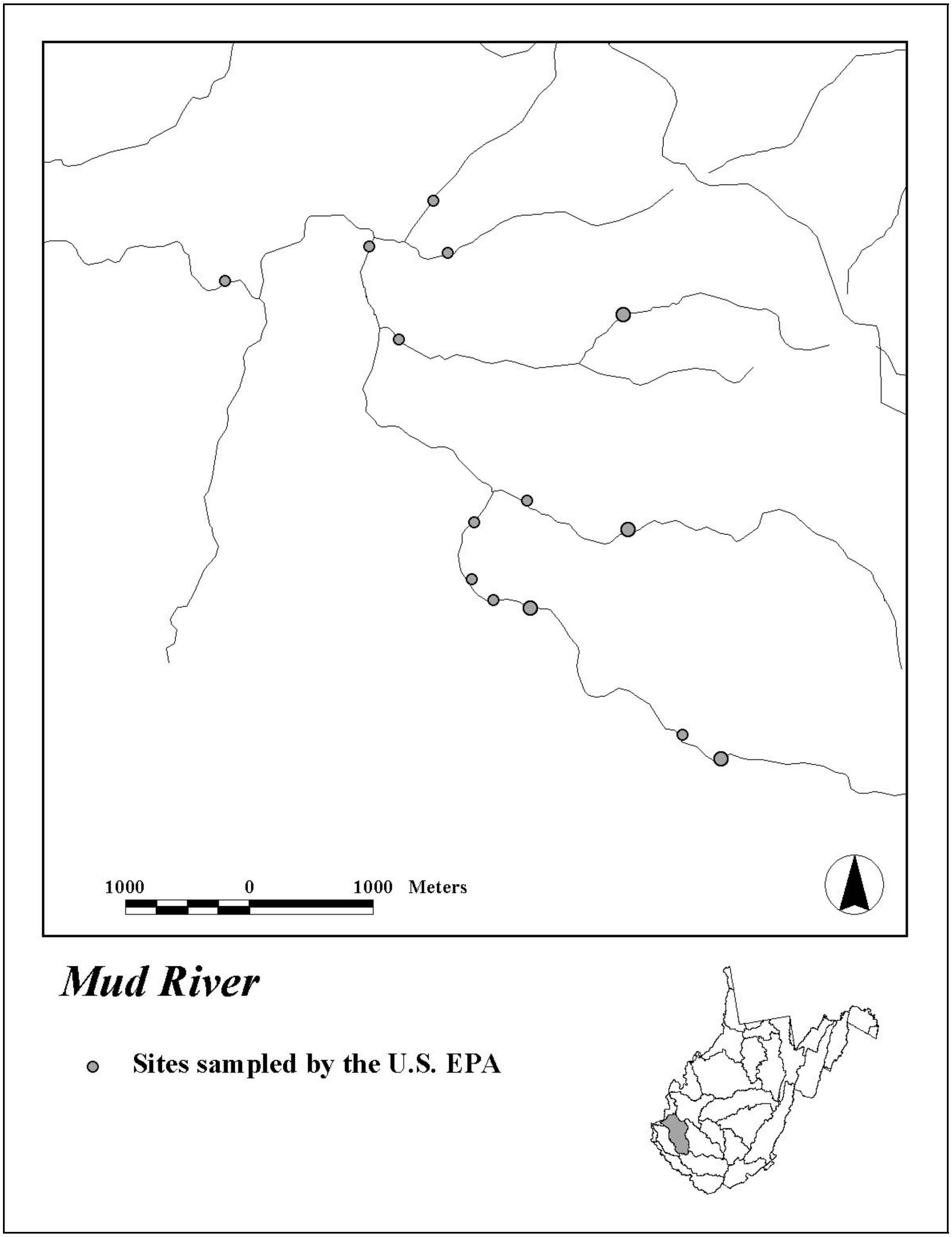


Figure 2-2. Sites sampled in the Mud River Watershed.

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

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 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).

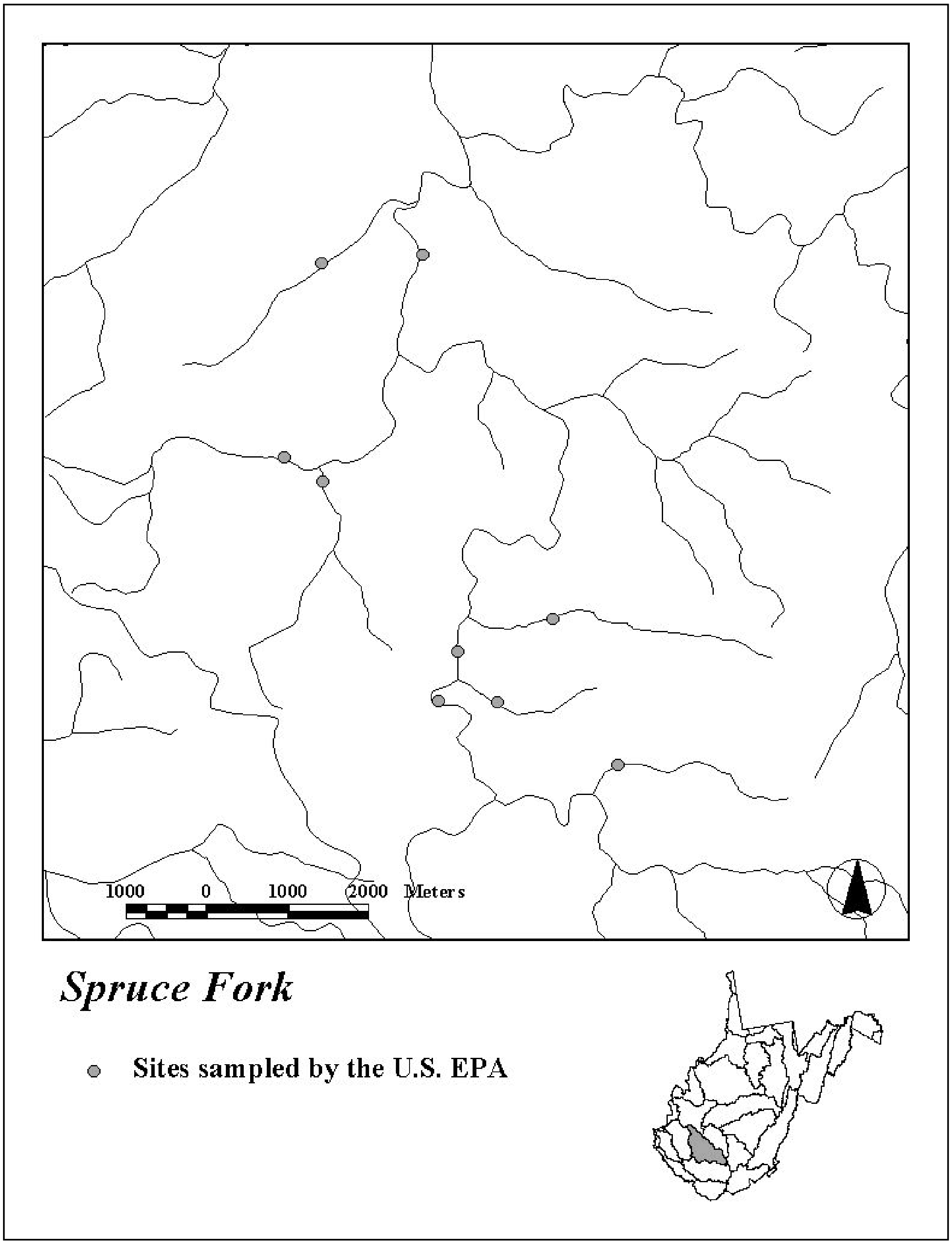


Figure 2-3. Sites sampled in the Spruce Fork Watershed.

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

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 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).

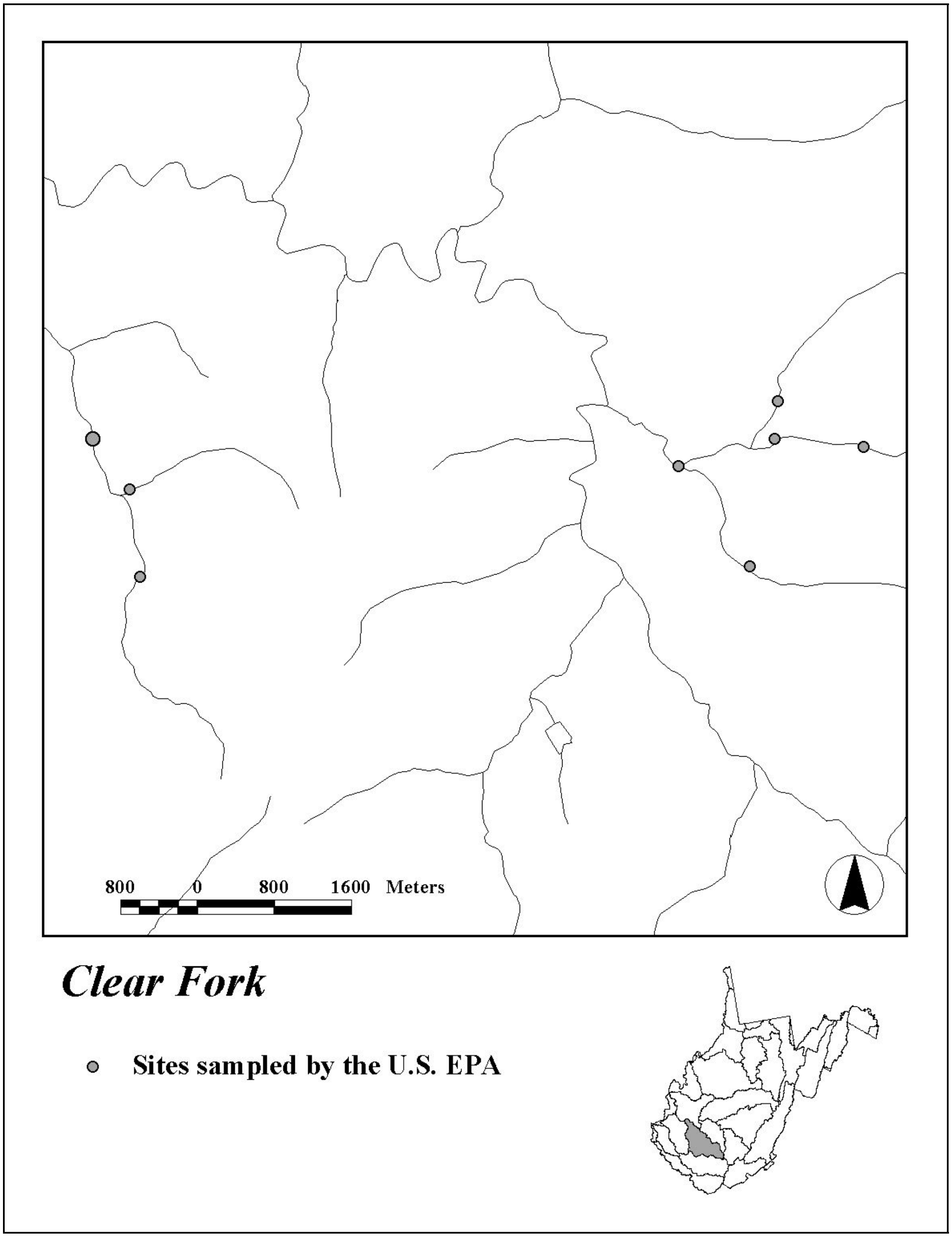


Figure 2-4. Sites sampled in the Clear Fork Watershed.

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

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 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).

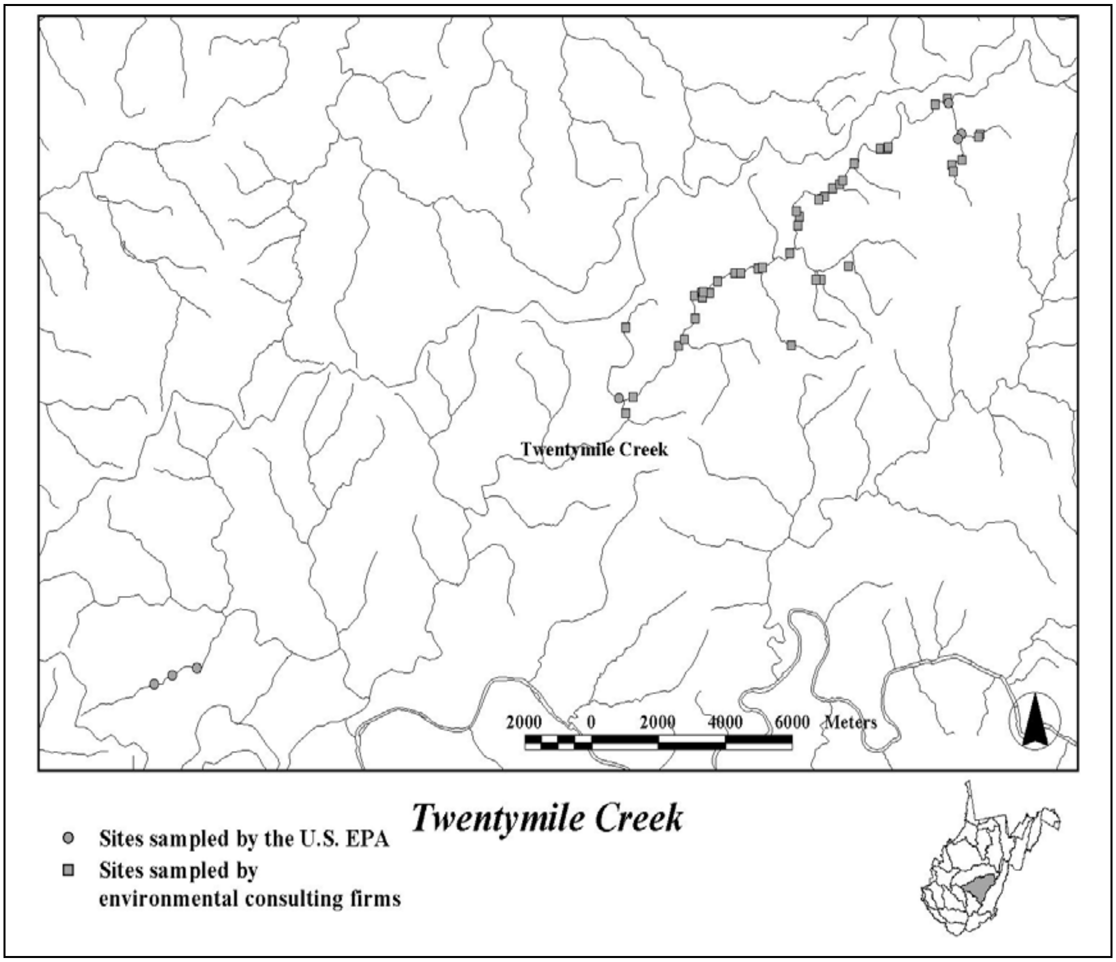


Figure 2-5. Sites sampled in the Twentymile Creek Watershed.

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).

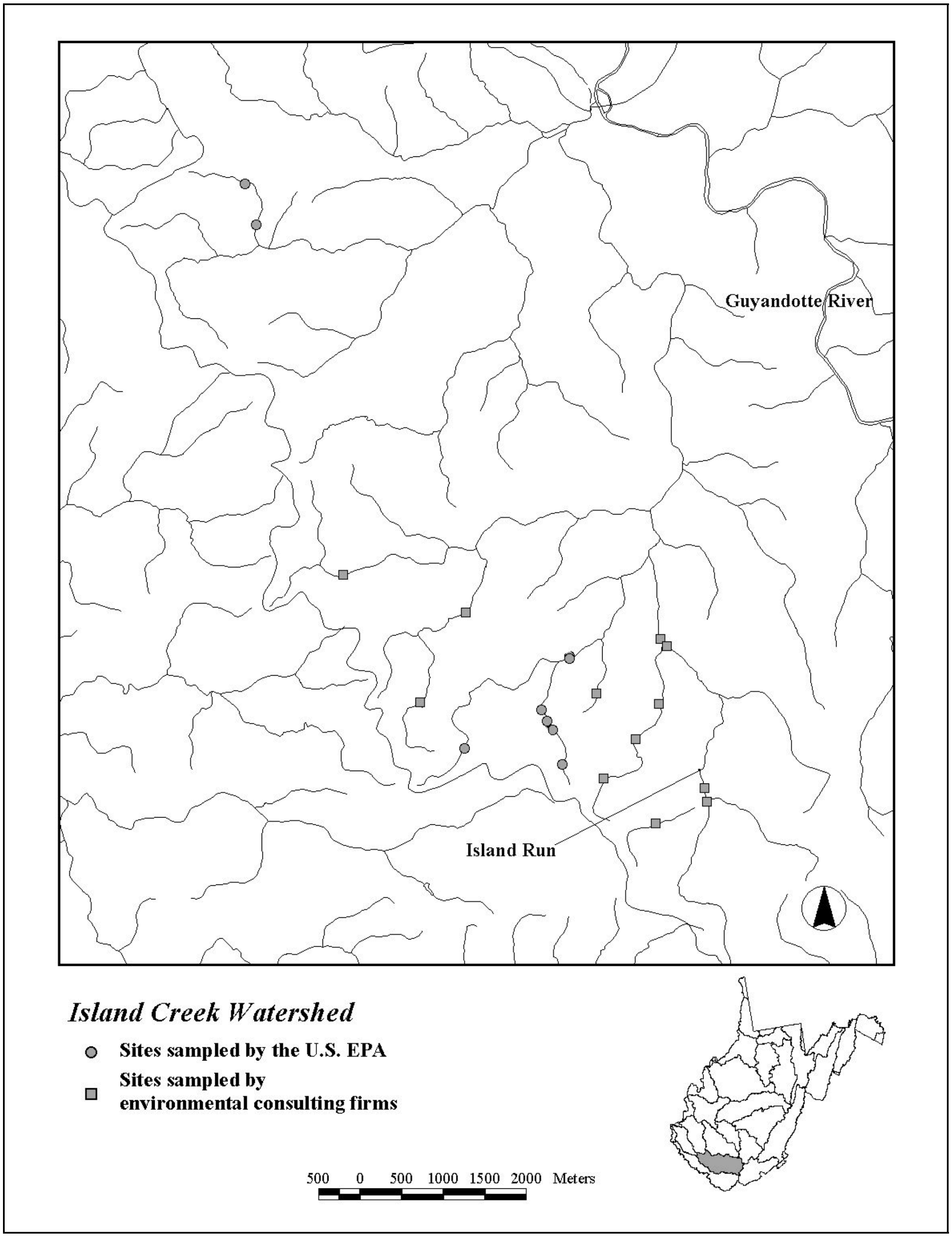


Figure 2-6. Sites sampled in the Island Creek Watershed.

Table 2-5. Sites sampled in the Island Creek Watershed.

Site ID/OrganizationStream Name	Stream Name	EIS Class
U.S. EPA Region 3 Sites		
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.

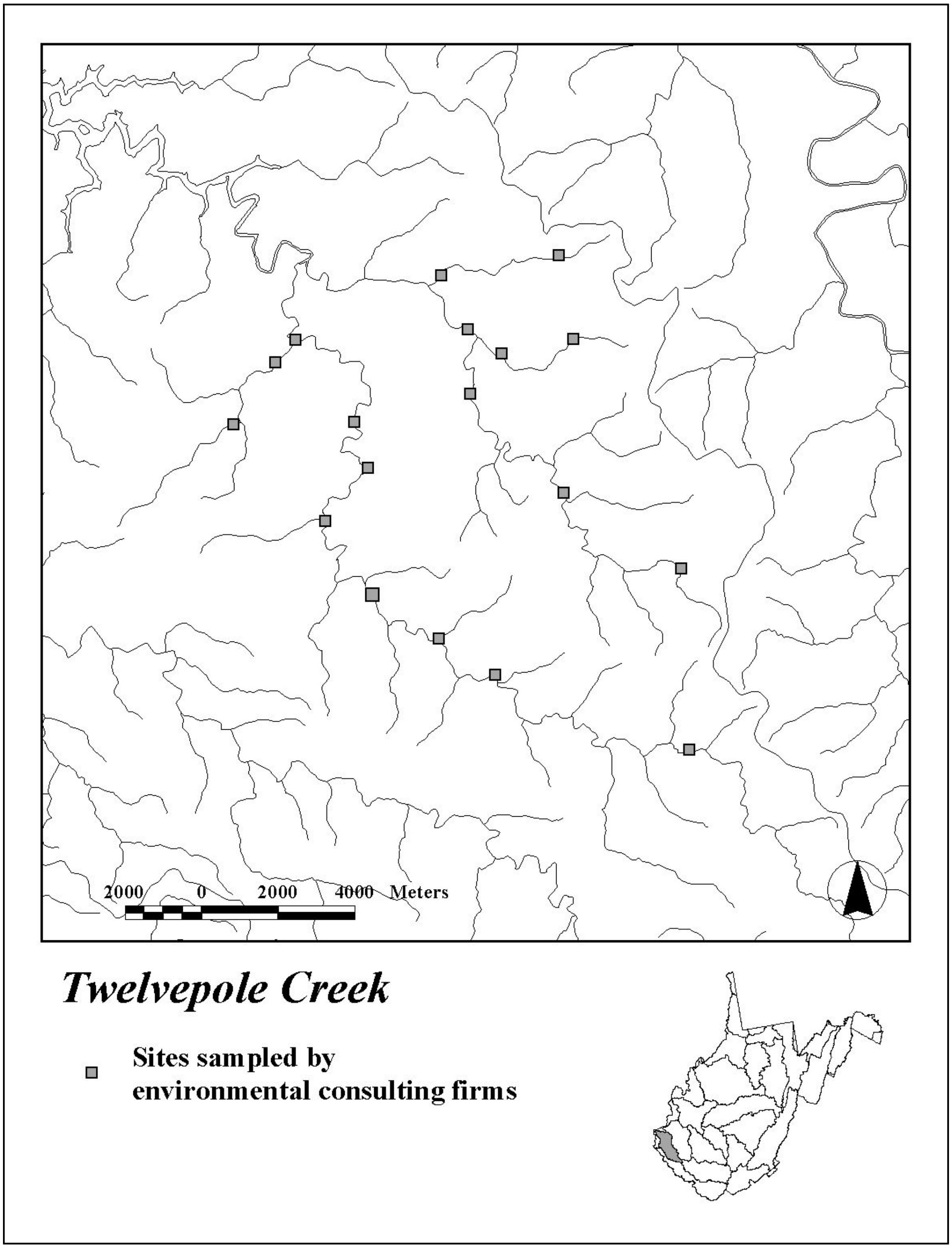


Figure 2-7. Sites sampled in the Twelvepole Creek Watershed.

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 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.

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(NO3) + Nitrite (NO2)	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

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 Creek1	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.

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.

Table 3-2. Number of sites and D-frame kick net samples available in each watershed and in each EIS class.

Watershed	EIS Class: Unmined		Filled		Filled/ Residential		Mined		Mined/ Residential		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

[1]Because there were only two Mined/Residential sites, this EIS class was not used in any of the analyses for this report.

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.

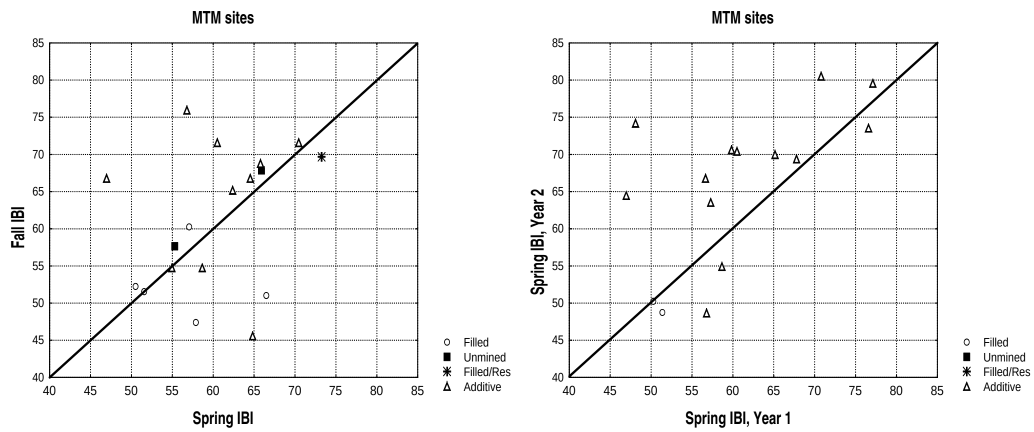


Figure 3-1. Scatter plots showing IBI scores of sites sampled multiple times. The left plot shows autumn samples versus spring samples and the right plot shows spring Year 2 samples versus spring Year 1 samples.

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.

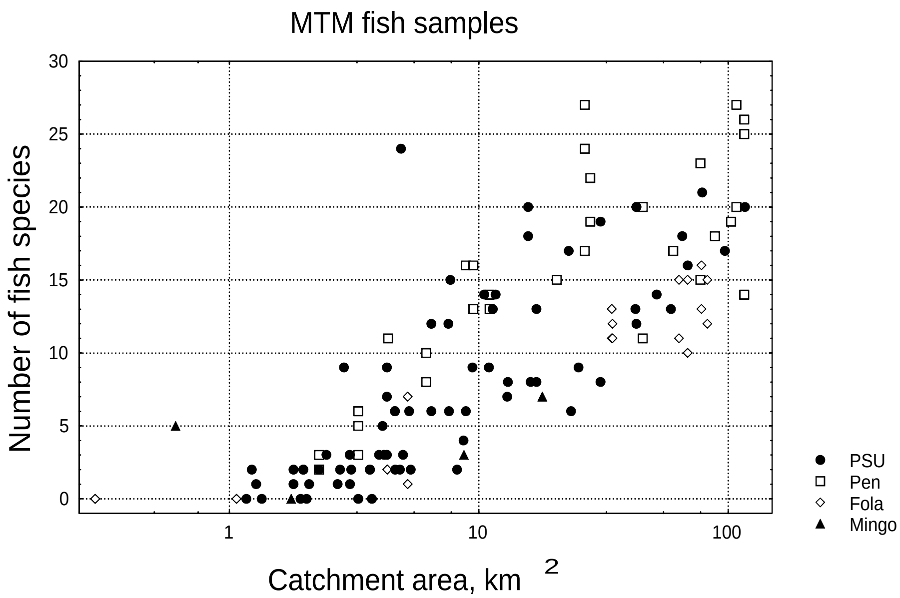


Figure 4-1. Number of fish species captured versus stream catchment area. Symbols identify sampling organizations: PSU=Penn State; Pen = Pen Coal (REIC); Fola = Fola Coal (Potesta); Mingo = Mingo-Logan Coal (BMI).

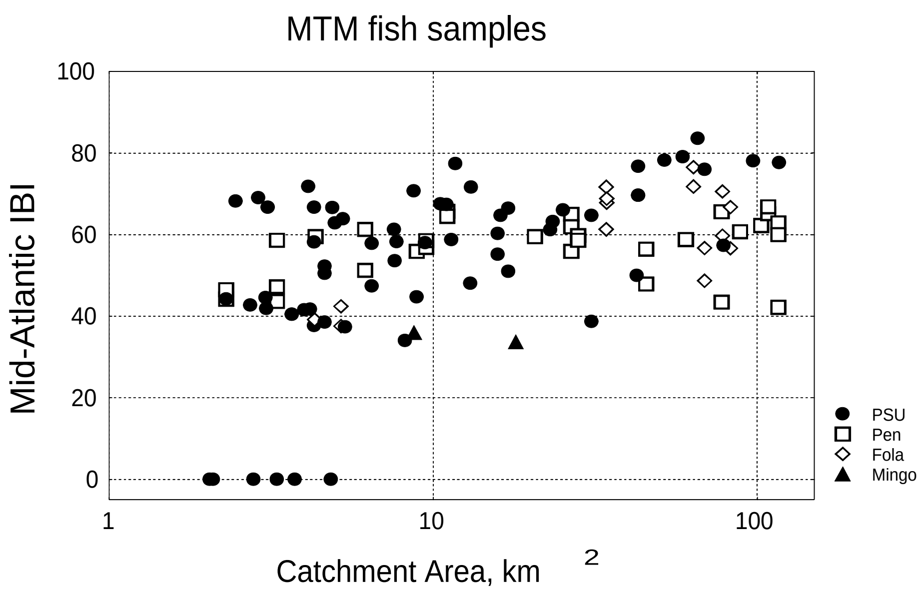


Figure 4-2. Calculated Fish IBI and watershed catchment area, all MTM fish samples from sites with catchment > 2km^2. Symbols identify sampling organizations: PSU=Penn State; Pen = Pen Coal (REIC); Fola = Fola Coal (Potesta); Mingo = Mingo-Logan Coal (BMI).

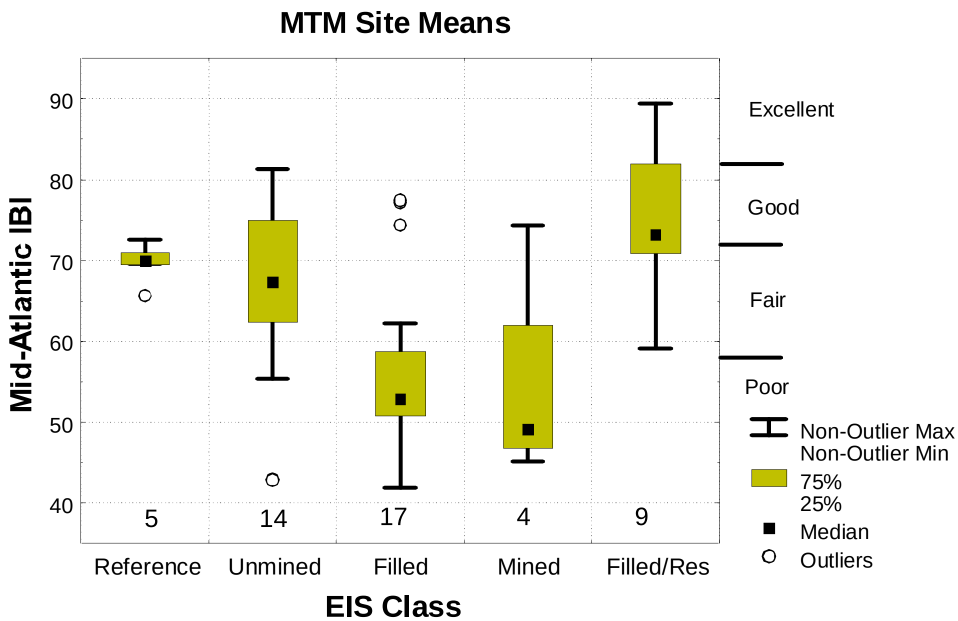


Figure 4-3. A Box-and-Whisker plot of the mean IBI scores from sampling sites in five EIS classes. Catchments less than 2 km^2 and samples with less than ten fish were excluded. Numbers below boxes indicate sample size. Reference sites were the five regional reference sites in Big Ugly Creek, outside 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.

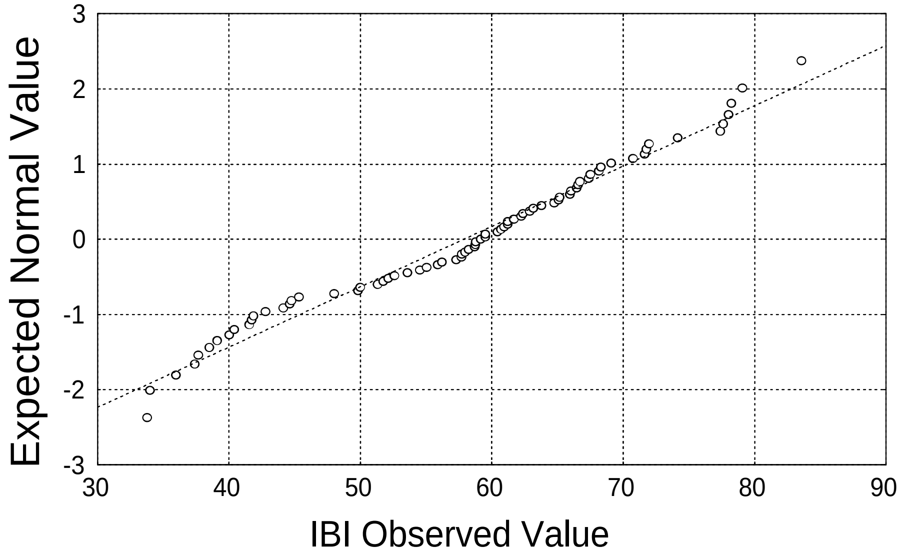


Figure 4-4. Normal probability plot of IBI scores from EIS classes.

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			

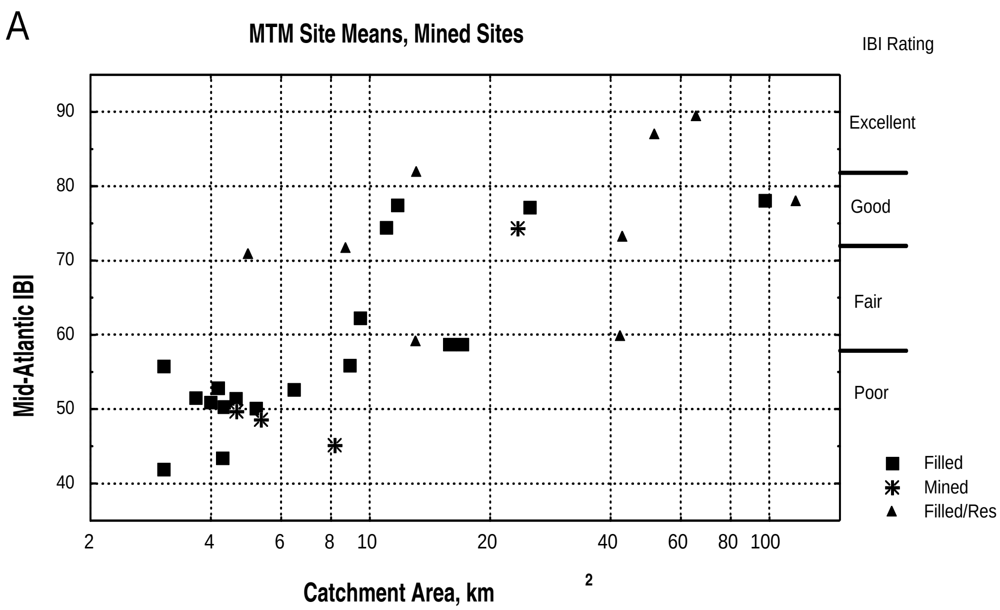
R-Square	Coefficient of Variance	Root MSE	Index Mean
0.334	17.022	10.783	63.350

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.



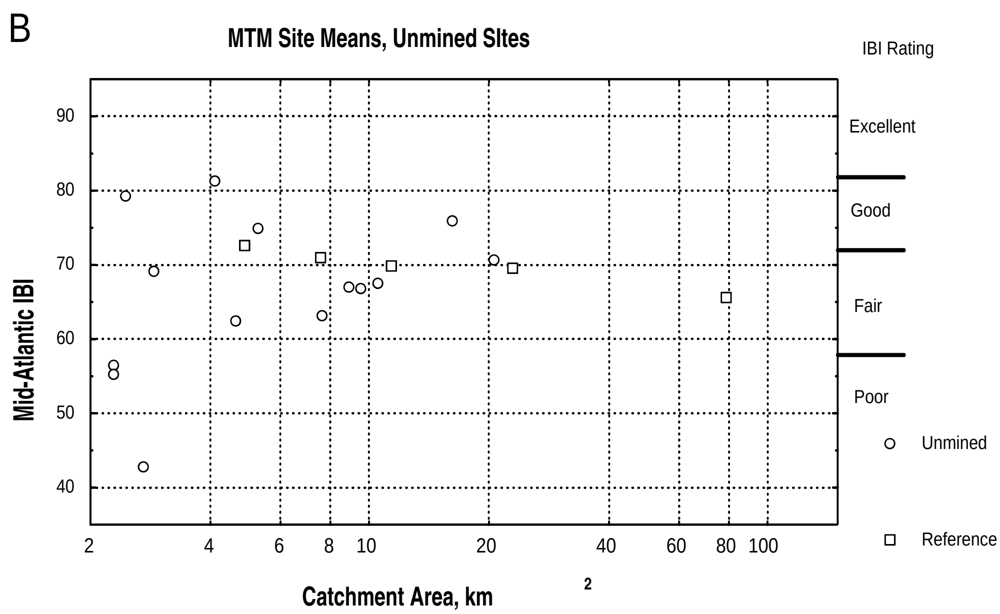


Figure 4-5. The IBI scores for different site classes, by watershed area. Assessment categories (McCormick et al.2001) are shown on right. A) Filled, Mined, and Filled/ Residential sites. B) Unmined and Reference (Big Ugly Creek) sites.

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).

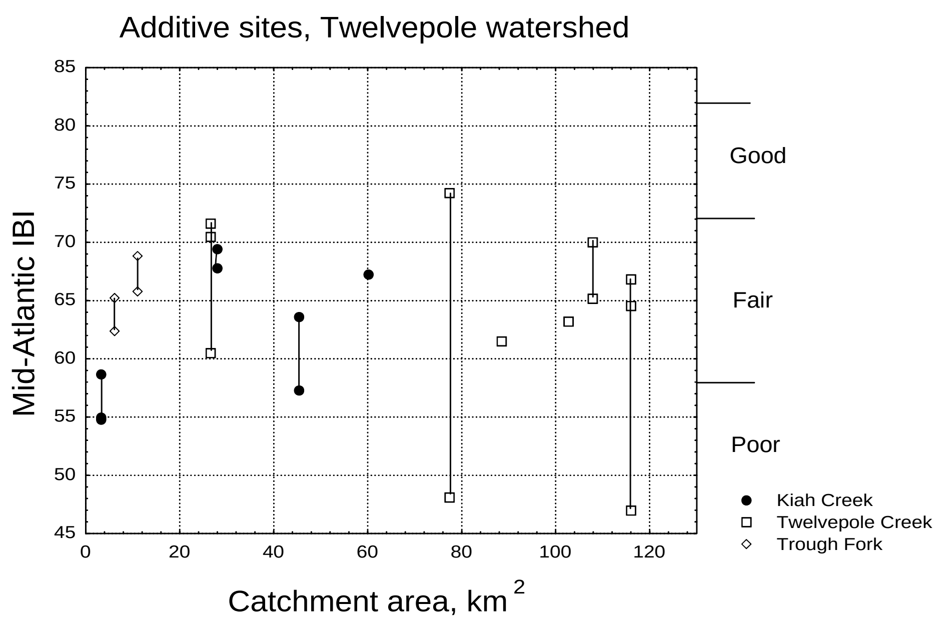


Figure 4-6. The IBI scores from the additive sites in the Twelvepole Creek Watershed. Multiple observations from single sites are connected with a vertical line.

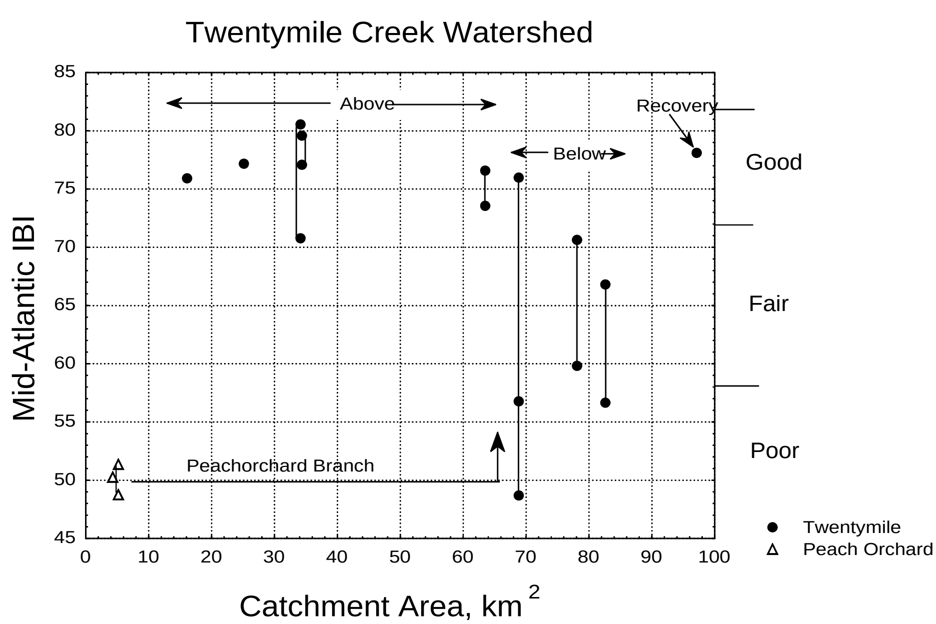


Figure 4-7. IBI scores from additive sites and Peachorchard Branch in the Twentymile Creek Watershed. Multiple observations from single sites are connected with a vertical line.

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 (NO3+ NO2)	Log Na	Log SO4	Log TDS	Log Zn
Log Mg	0.11							
Log Ni	-0.08	0.53						
Log (NO3+NO2)	0.40	0.65	0.37					
Log Na	0.16	0.40	-0.08	0.65				
Log SO4	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 its 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 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 4-11. 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

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

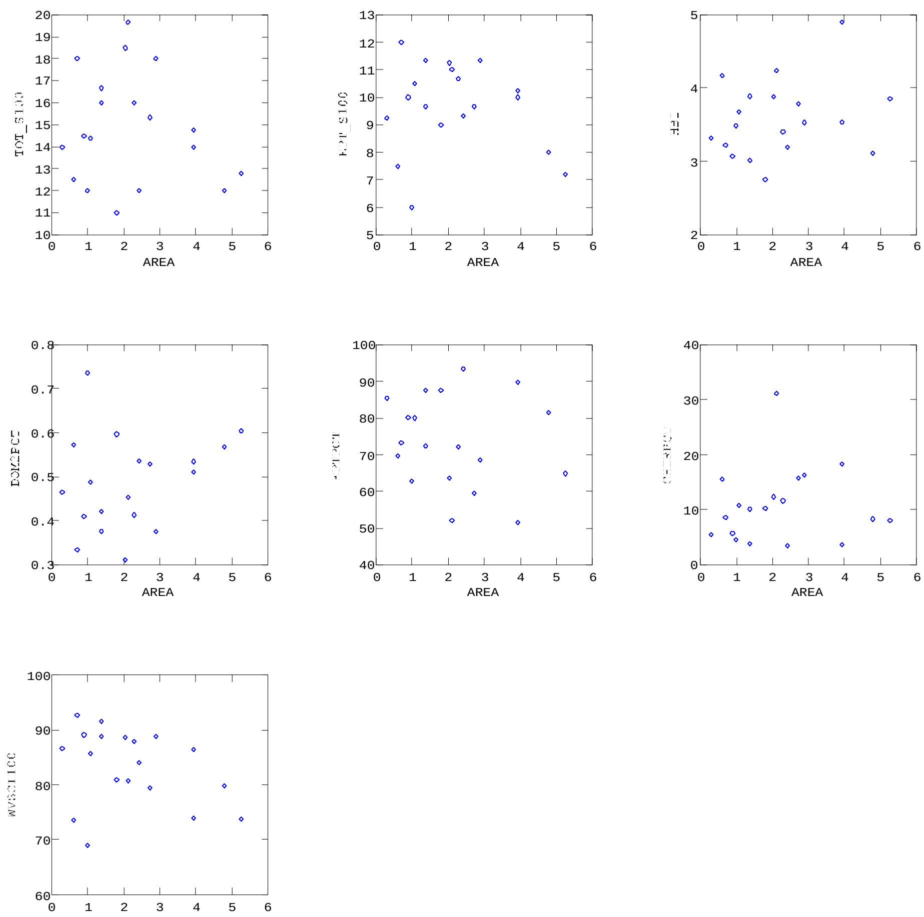


Figure 4-8. The WVSCI and its metric scores versus catchment area in Unmined streams.

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 its 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.

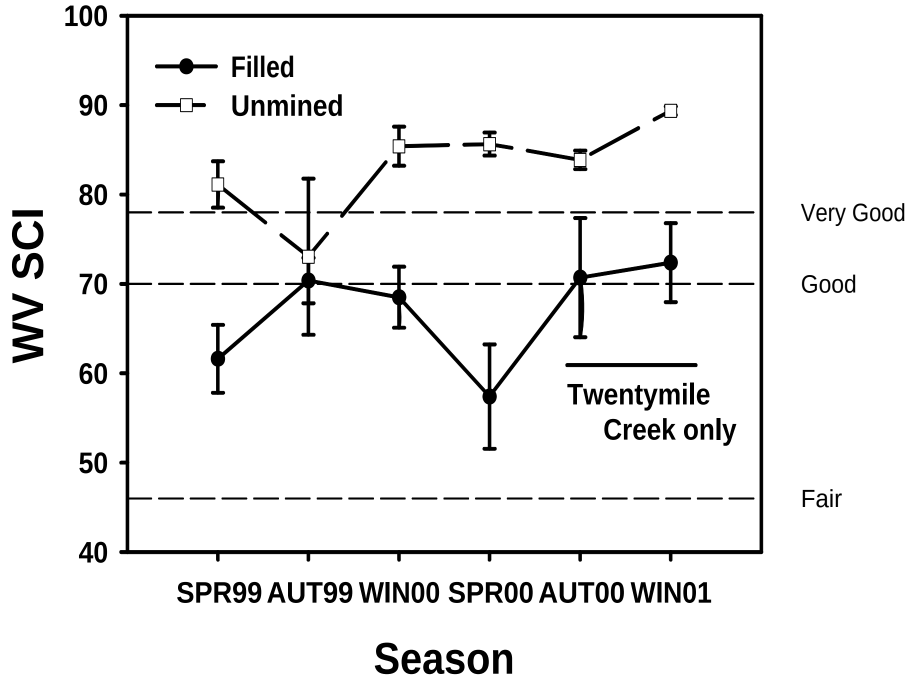


Figure 5-1. Mean WVSCI scores in the Unmined and Filled EIS classes versus sampling season. Error bars are 1 SE. Data for autumn 2000 and winter 2001 only used private organization data for the Twentymile Creek Watershed. The condition categories are based on Green et al. (2000 Draft).

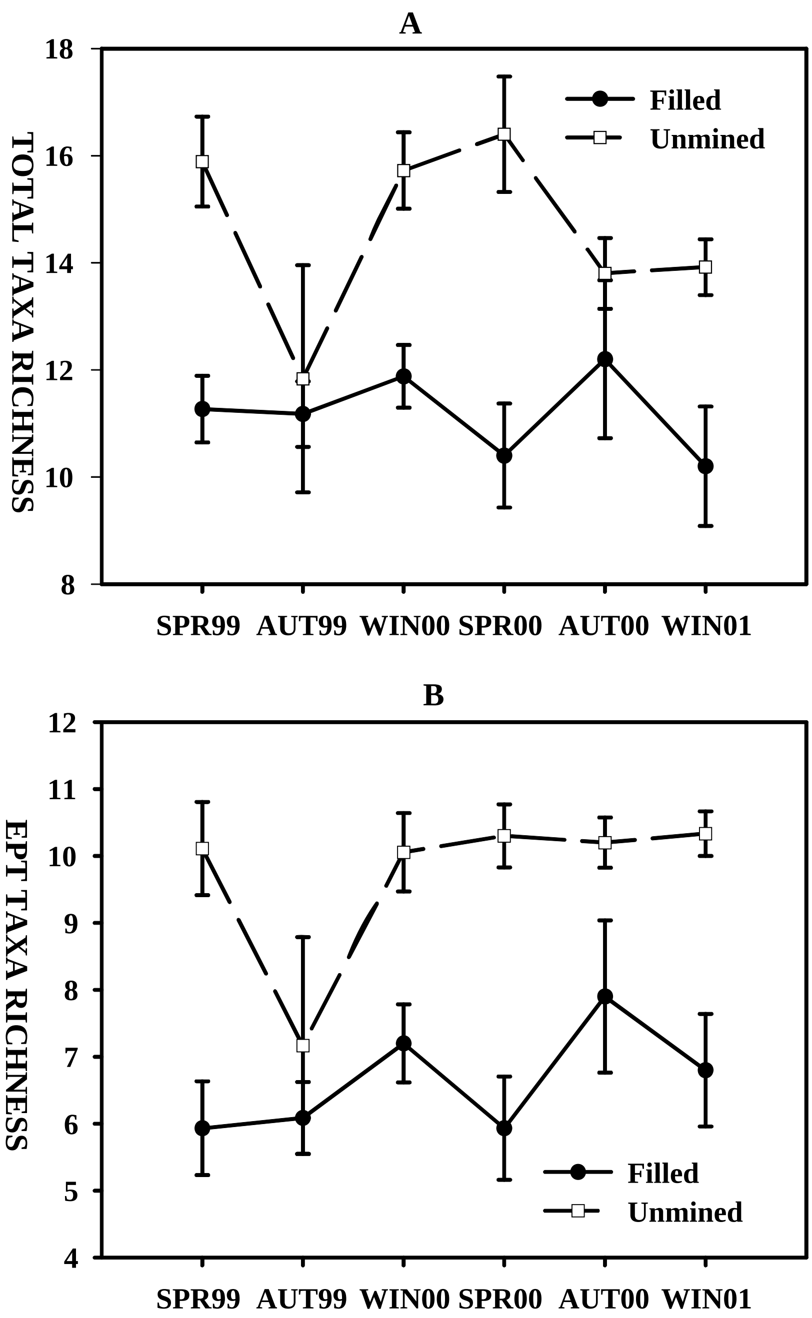


Figure 5-2. (A) Mean Total Taxa richness in the Unmined and Filled EIS classes versus sampling season. (B) Mean EPT Taxa richness in the Unmined and Filled EIS classes versus sampling season. Error bars are 1 SE. Data for autumn 2000 and winter 2001 only used private organization data for the Twentymile 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.
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**

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 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 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**
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.
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 c-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)

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 m2 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)

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.
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.

(Continued)

Benthic Macroinvertebrate Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
Sampler Used	Sampling was conducted according to Barbour et al. (1999). A 0.5-m rectangular kick net was used to composite four ¼-m2 samples.	In the autumn of 1999 and the spring of 2000, four ¼-m2 samples collected with a D-frame kick net were composited. In the autumn of 2000, six Surber samples were collected and four ¼-m2 samples collected with a D-frame kick net were composited. In the spring of 2001, four Surber samples, were collected and four ¼-m2 samples were collected with a D-frame kick net and composited.	Four ¼-m2 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-m2 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-ft2 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.
Kick Net Procedures	The procedures in Barbour et al. (1999) were modified so that 1 m2 of substrate was sampled at each site.	The net was held downstream of the 0.25-m2 area that was to be sampled. All rocks and debris that were in the 0.25-m2 area were scrubbed and rinsed into the net and removed from the sampling area. Then, the substrate in the 0.25-m2 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 m2 upstream of net were brushed into the net. The substrate within 0.25 m2 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 0.25m2 was sampled. The procedure was repeated four times.

(Continued)

Benthic Macroinvertebrate Procedures (Continued)				
	U.S. EPA Region 3	**BMI**	**POTESTA**	**REIC**
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.
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.

(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.
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 (c 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)

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.

APPENDIX B: IBI COMPONENT METRIC VALUES

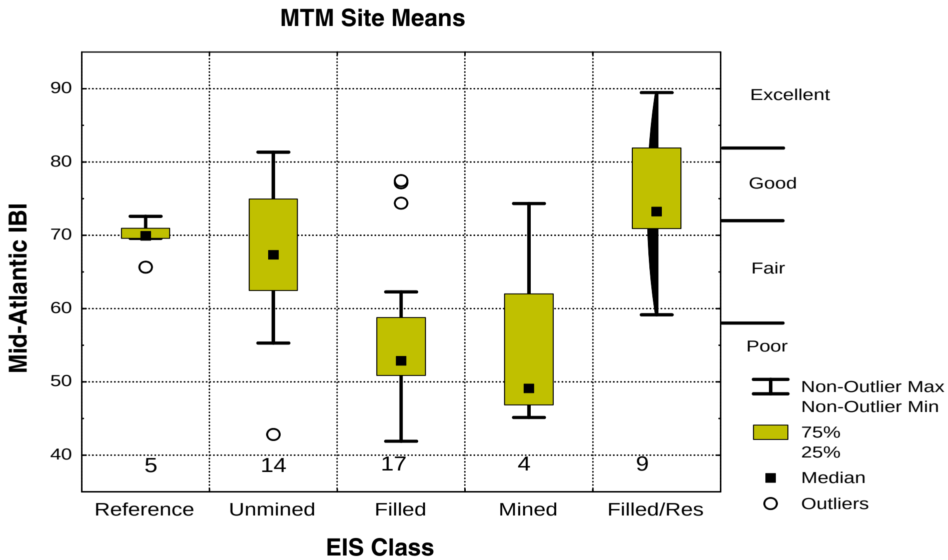

Figure B-1. Box plot of the IBI among EIS classes and regional reference sites. All taxa richness metrics were adjusted to a catchment area of 100 km^2.

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	--

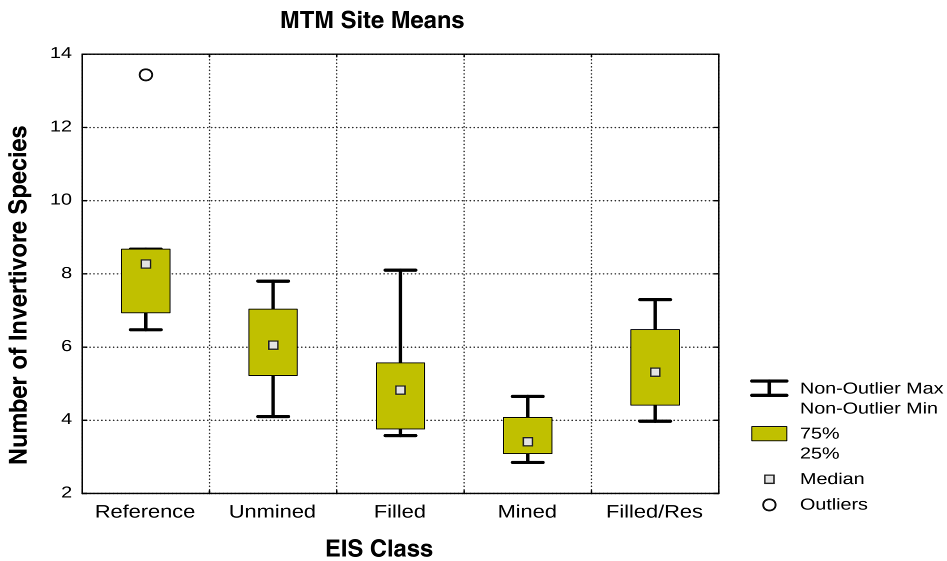

Figure B-2. Box plot of the Number of Benthic Invertivore Species among EIS classes and regional reference sites.

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	--

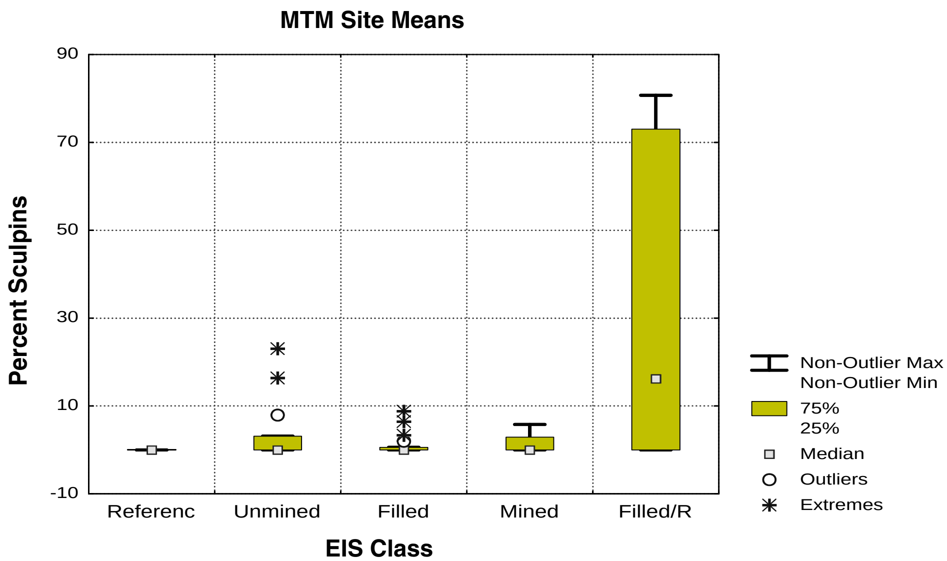

Figure B-3. Box plot of the Percent Cottidae(Sculpins) among EIS classes and regional reference sites.

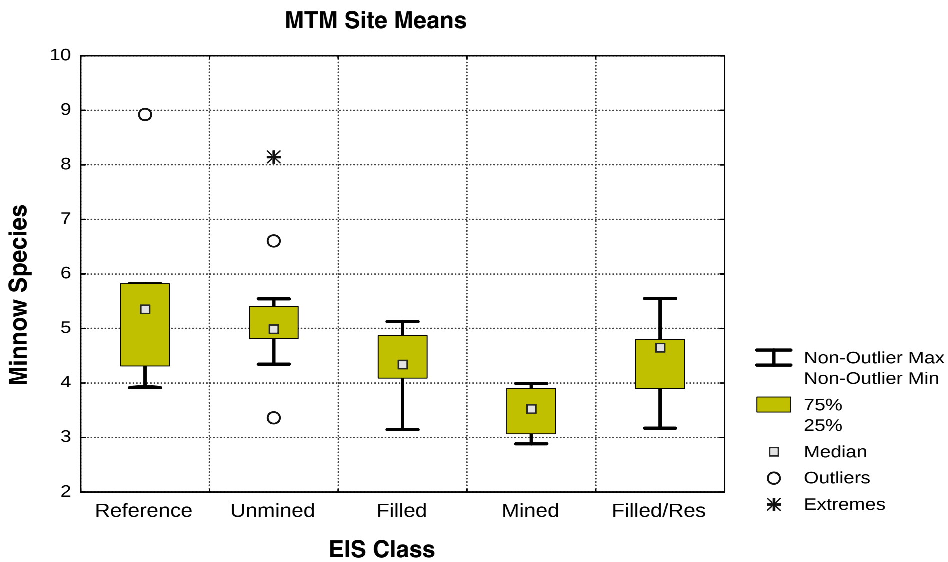

Figure B-4. Box plot of the Number of Native Cyprinidae (Minnow Species) among EIS classes and regional reference sites. This metric was adjusted to a catchment area of 100 km^2.

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	--

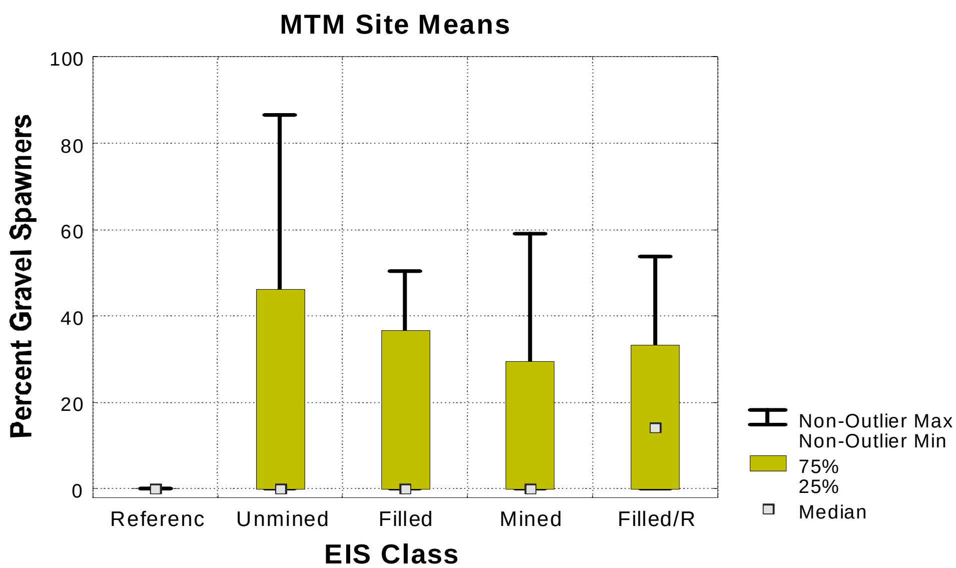

Figure B-5. Box plot of the Percent Gravel Spawners among EIS classes and regional reference sites.

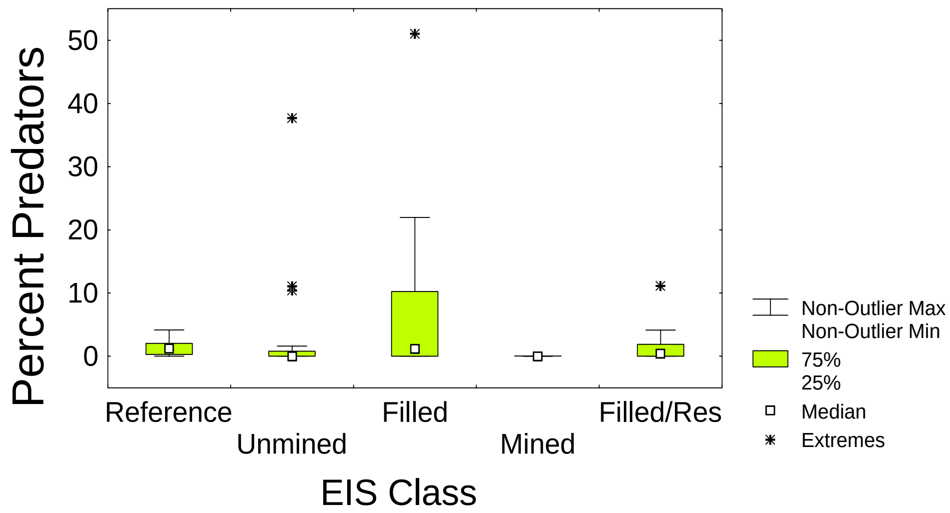

Figure B-6. Box plot of the Percent Piscivore/Invertivores (Predators) among EIS classes and regional reference sites.

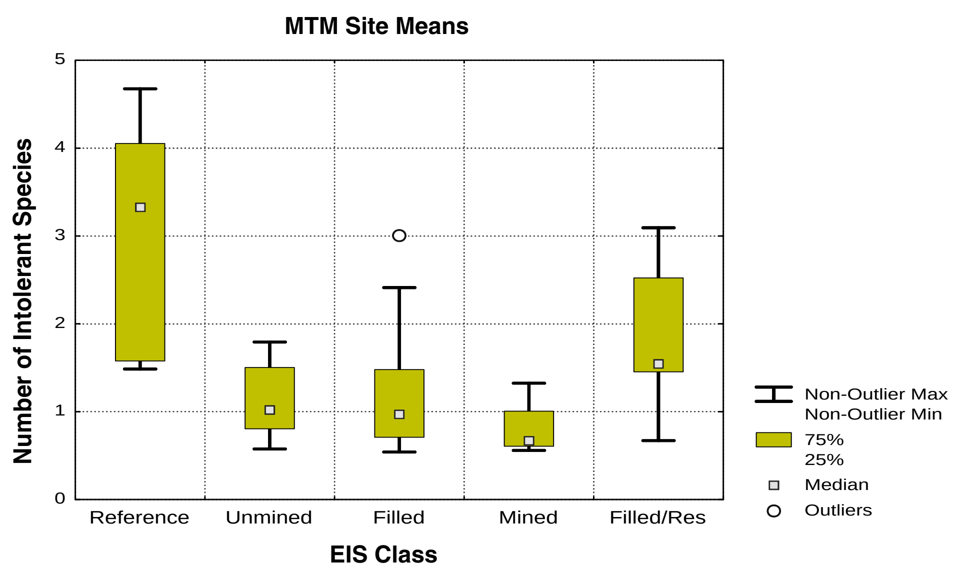

Figure B-7. Box plot of the Number of Intolerant Species among EIS classes and regional reference sites. This metric was adjusted to a catchment area of 100 km^2.

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	--

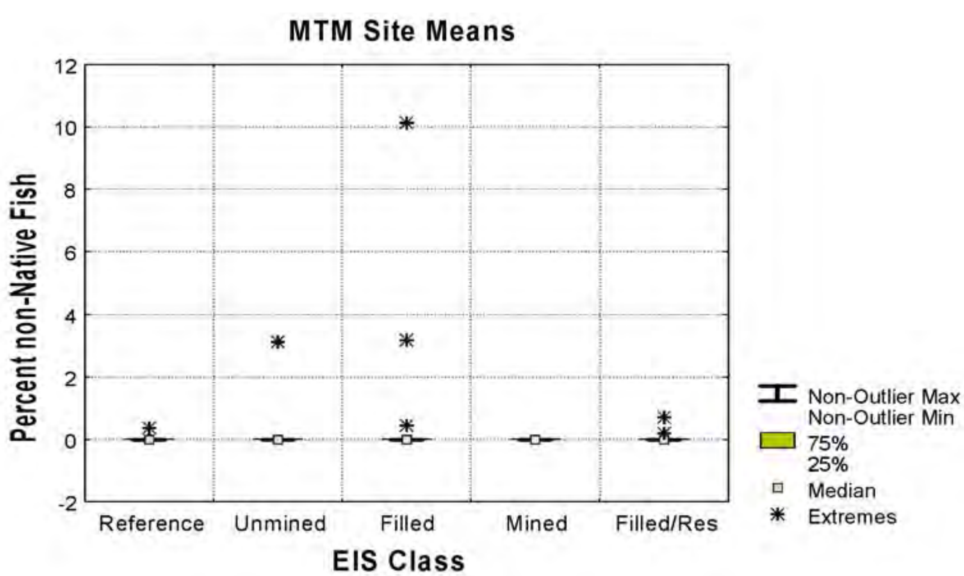

Figure B-8. Box plot of the Percent Exotic (Non-Native Fish) among EIS classes and regional reference sites.

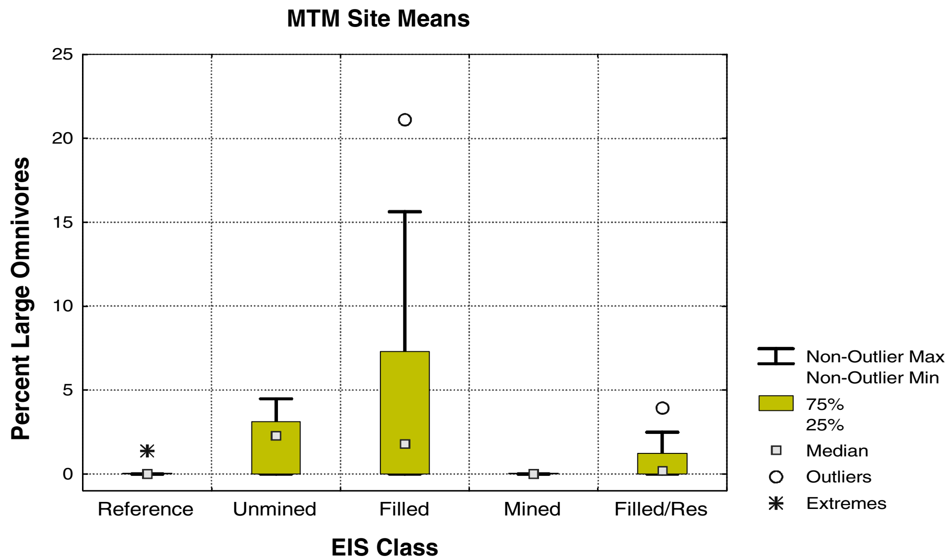

Figure B-9. Box plot of the Percent Macro Omnivores among EIS classes and regional reference sites.

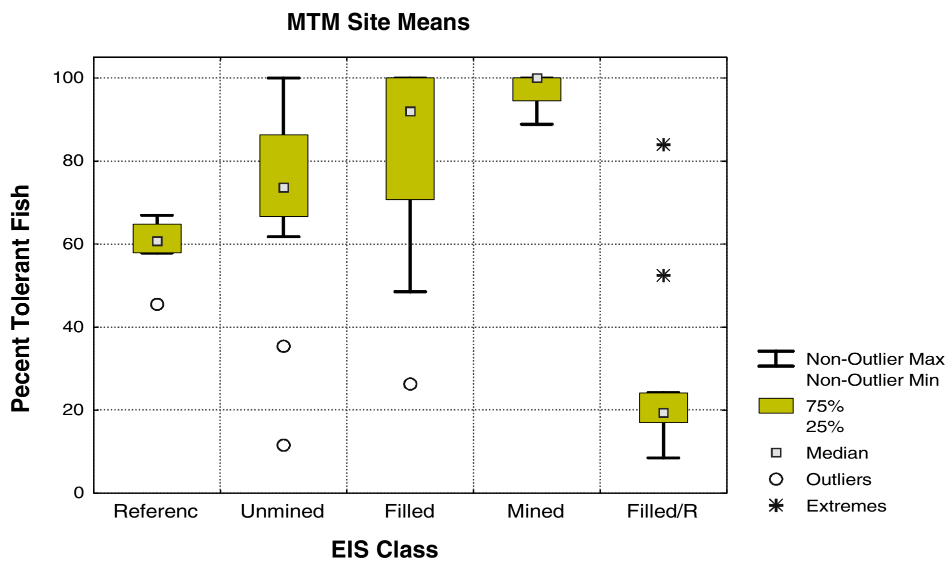

Figure B-10. Box plot of the Percent Tolerant Fish among EIS classes and regional reference sites.

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

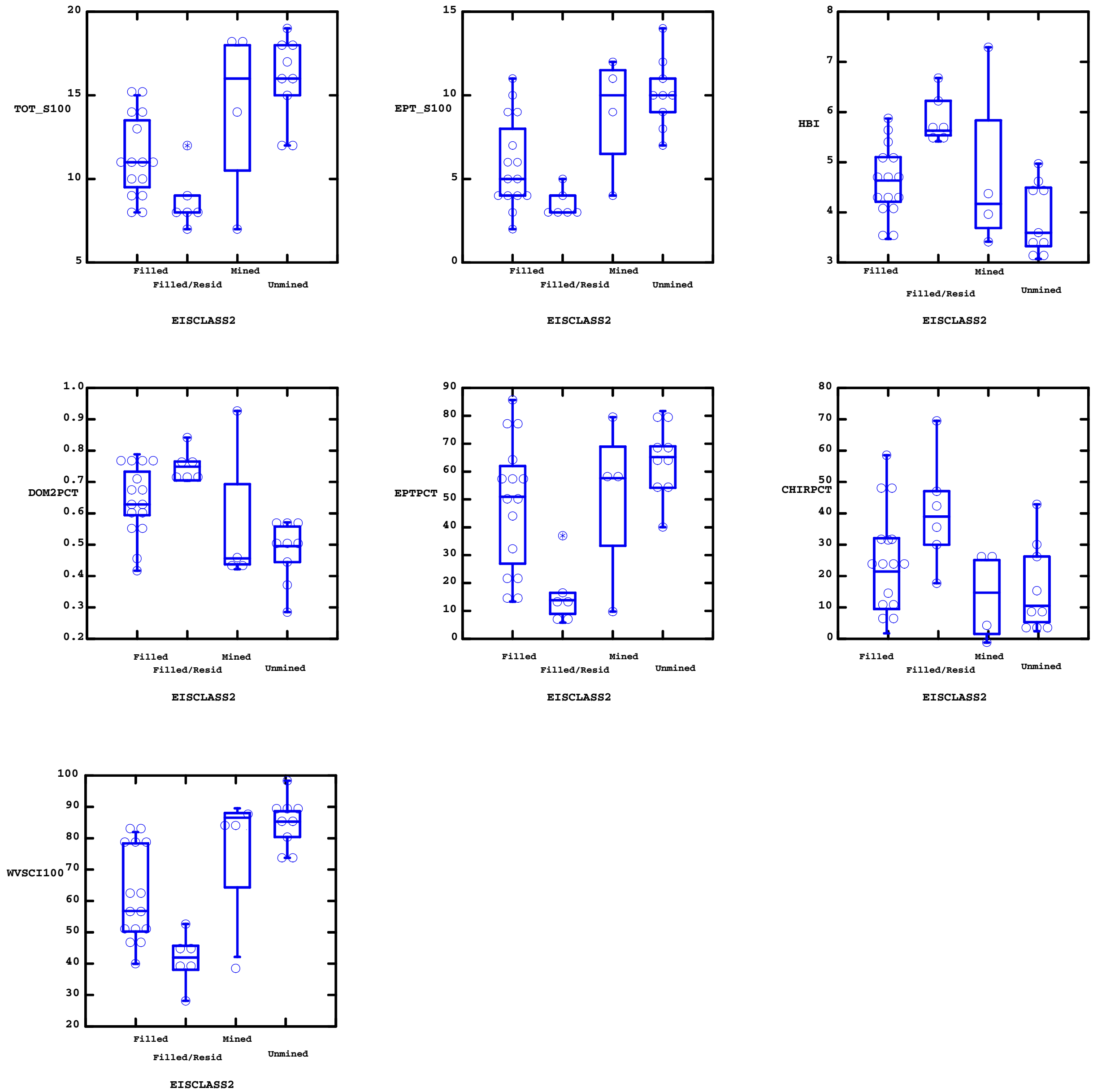

Figure C-1. Box plots of the WVSCI and its component metrics versus the EIS class for the spring 1999 season. Circles represent site scores.

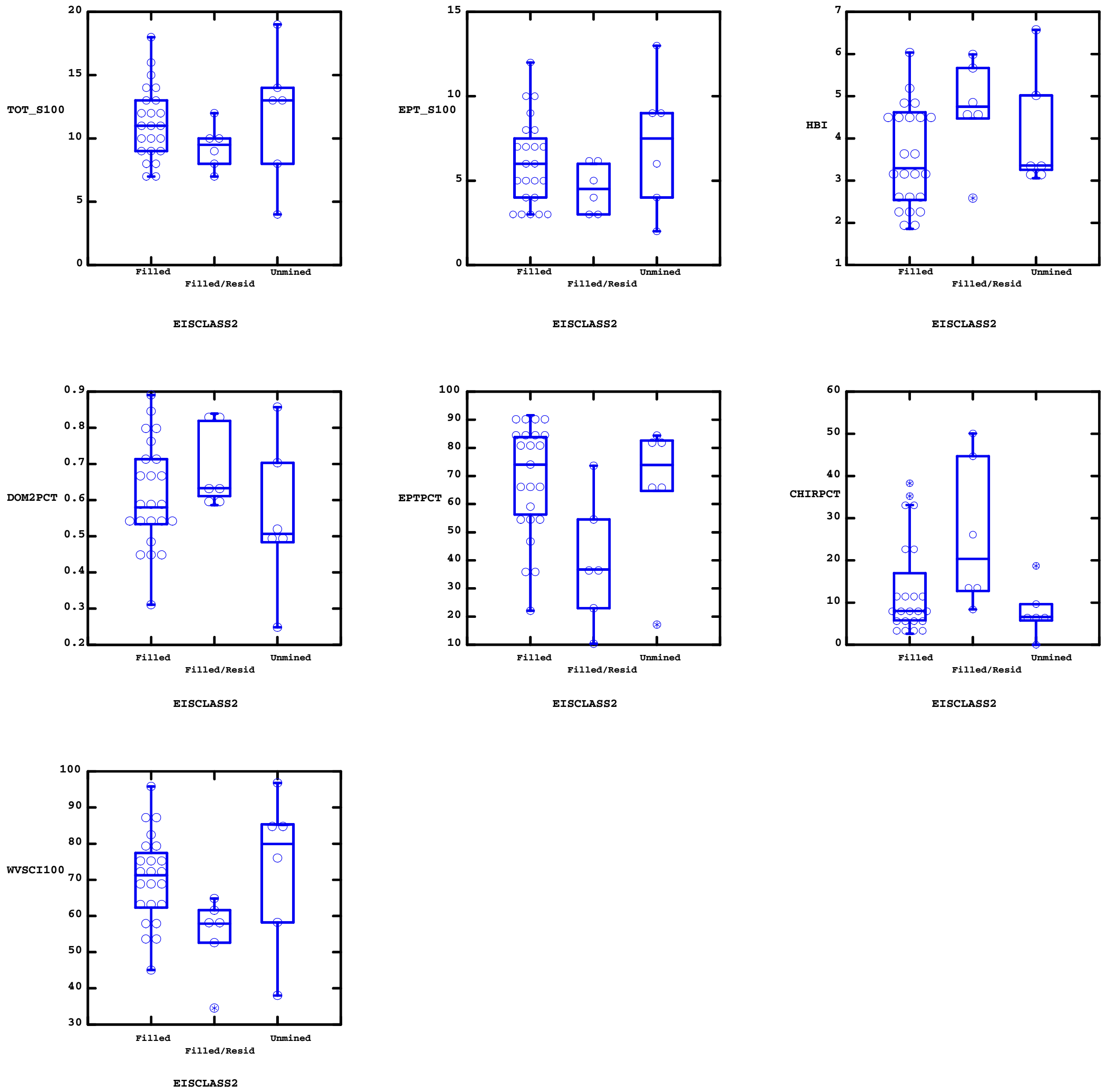

Figure C-2. Box plots of the WVSCI and its component metrics versus the EIS class for the autumn 1999 season. Circles represent site scores.

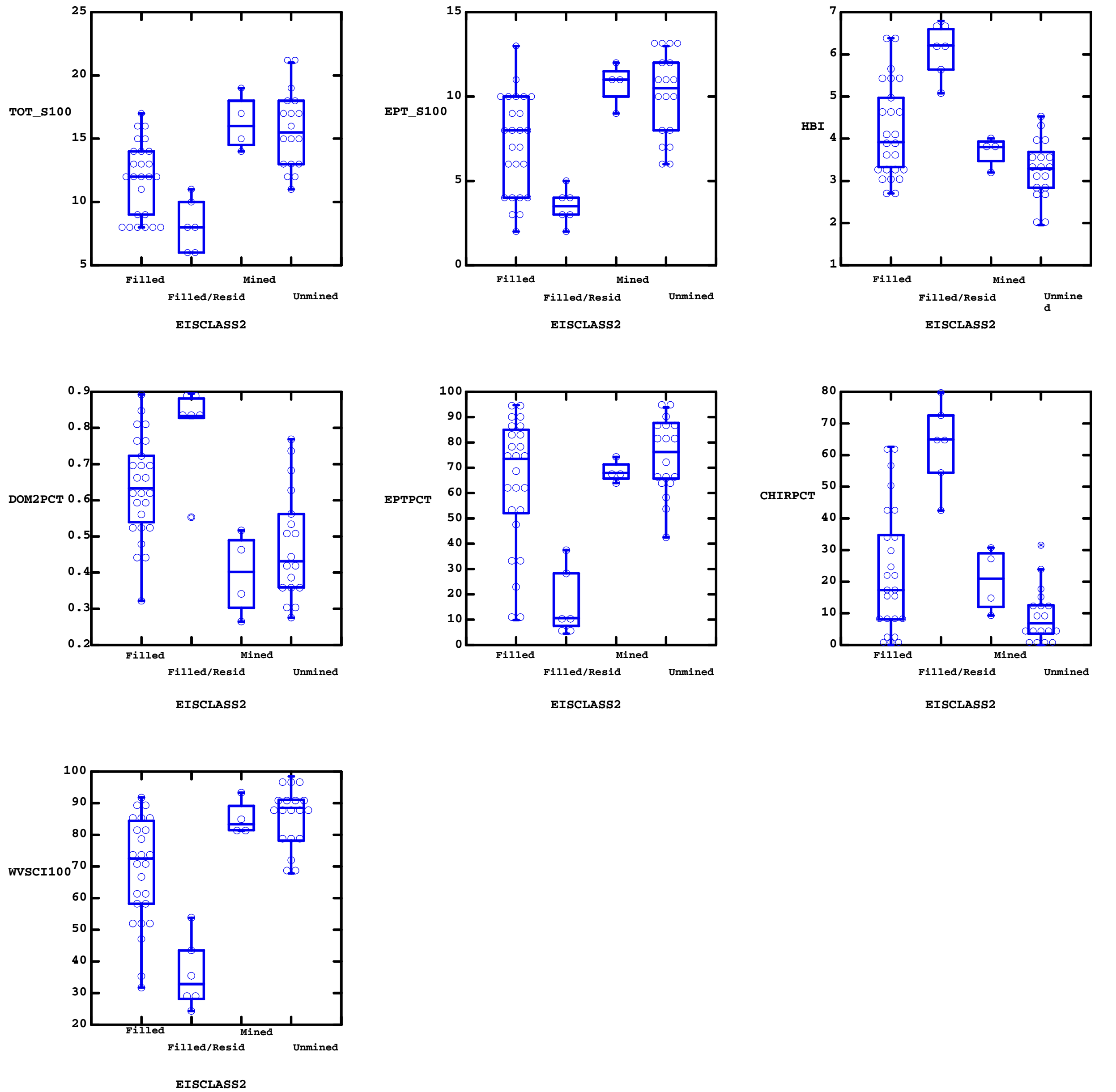

Figure C-3. Box plots of the WVSCI and its component metrics versus the EIS class for the winter 2000 season. Circles represent site scores.

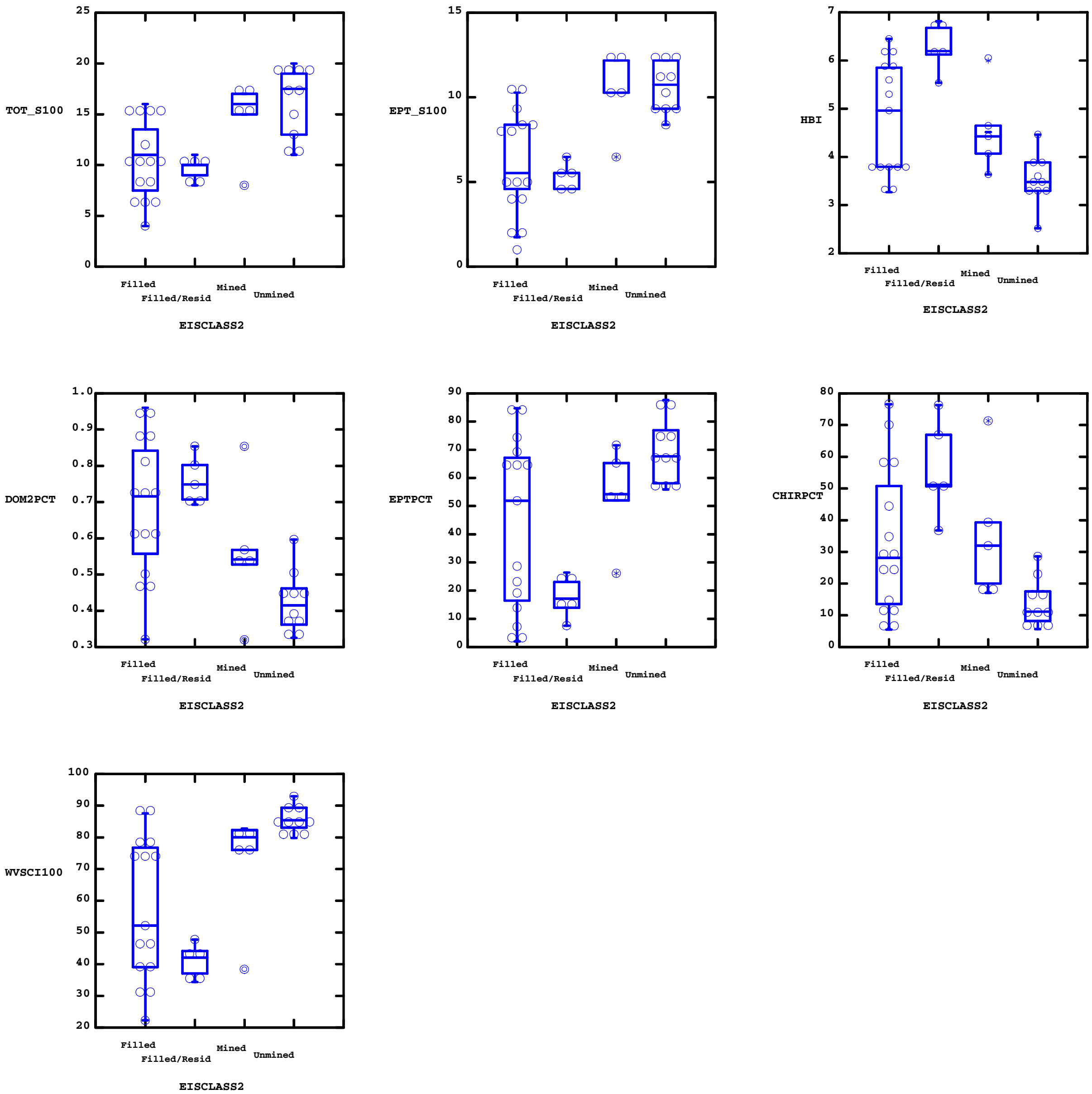

Figure C-4. Box plots of the WVSCI and its component metrics versus the EIS class for the spring 2000 season. Circles represent site scores.

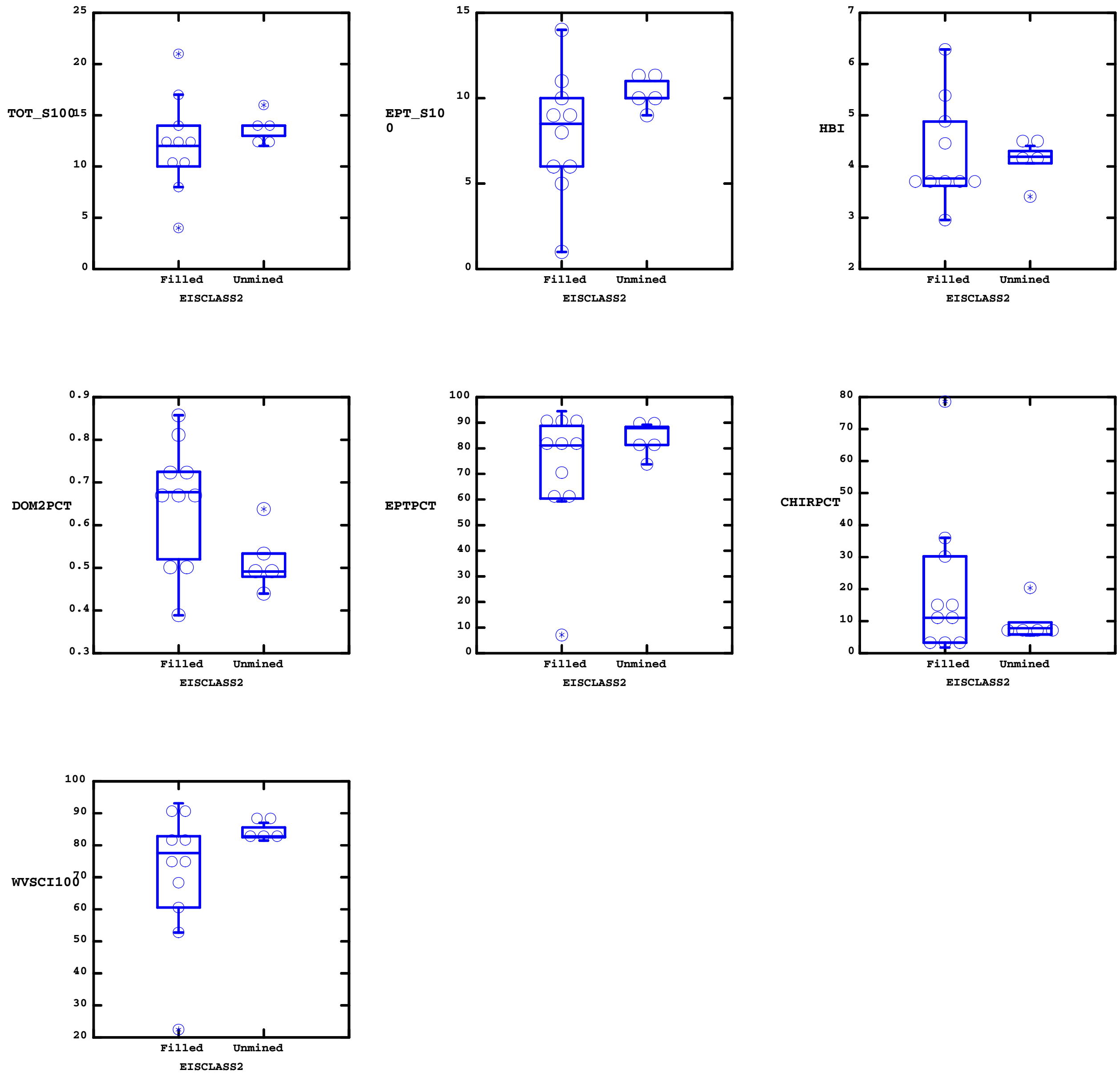

Figure C-5. Box plots of the WVSCI and its component metrics versus the EIS class for the autumn 2000 season. Circles represent site scores.

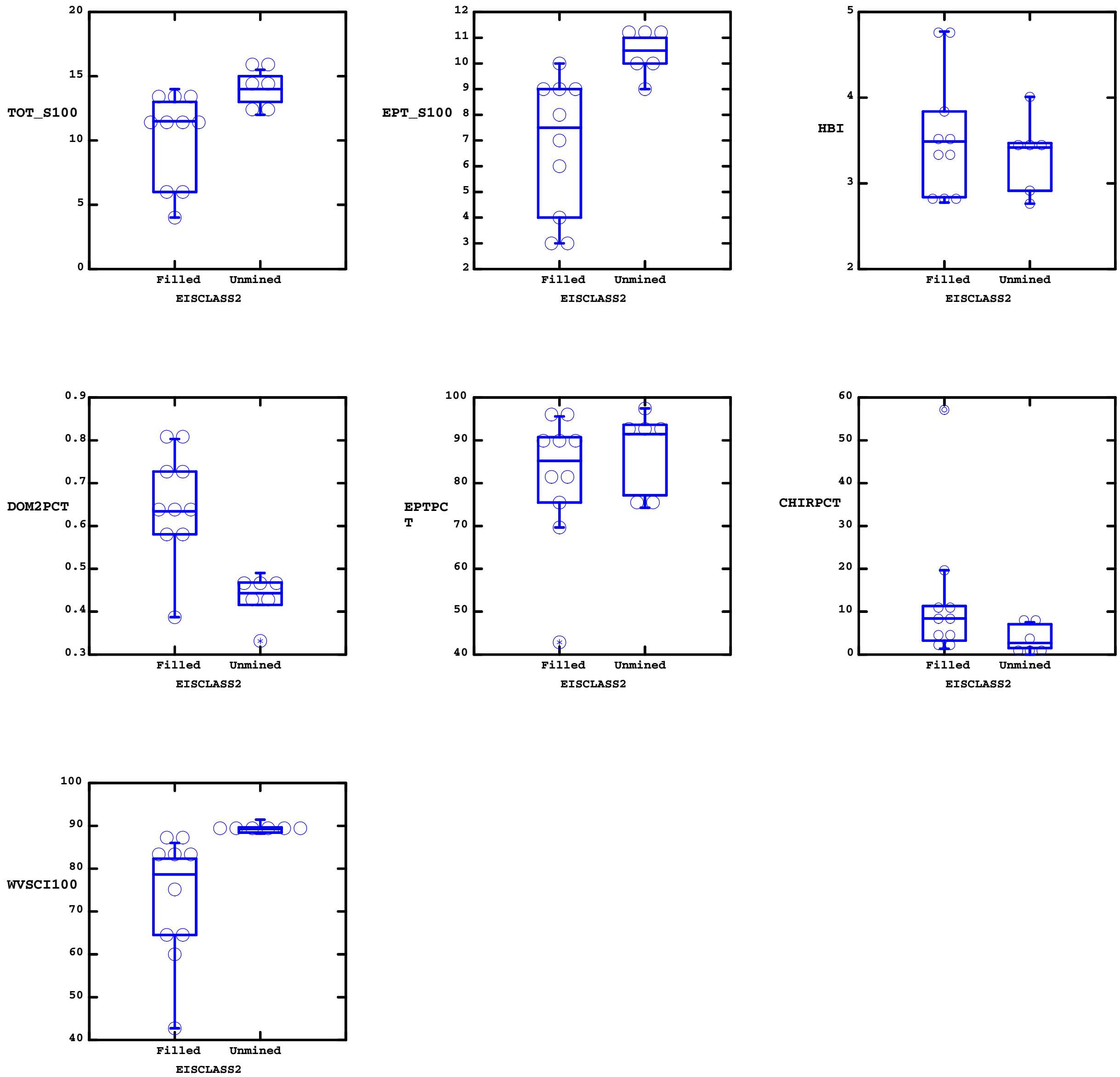

Figure C-6. Box plots of the WVSCI and its component metrics versus the EIS class for the winter 2001 season. Circles represent site scores.

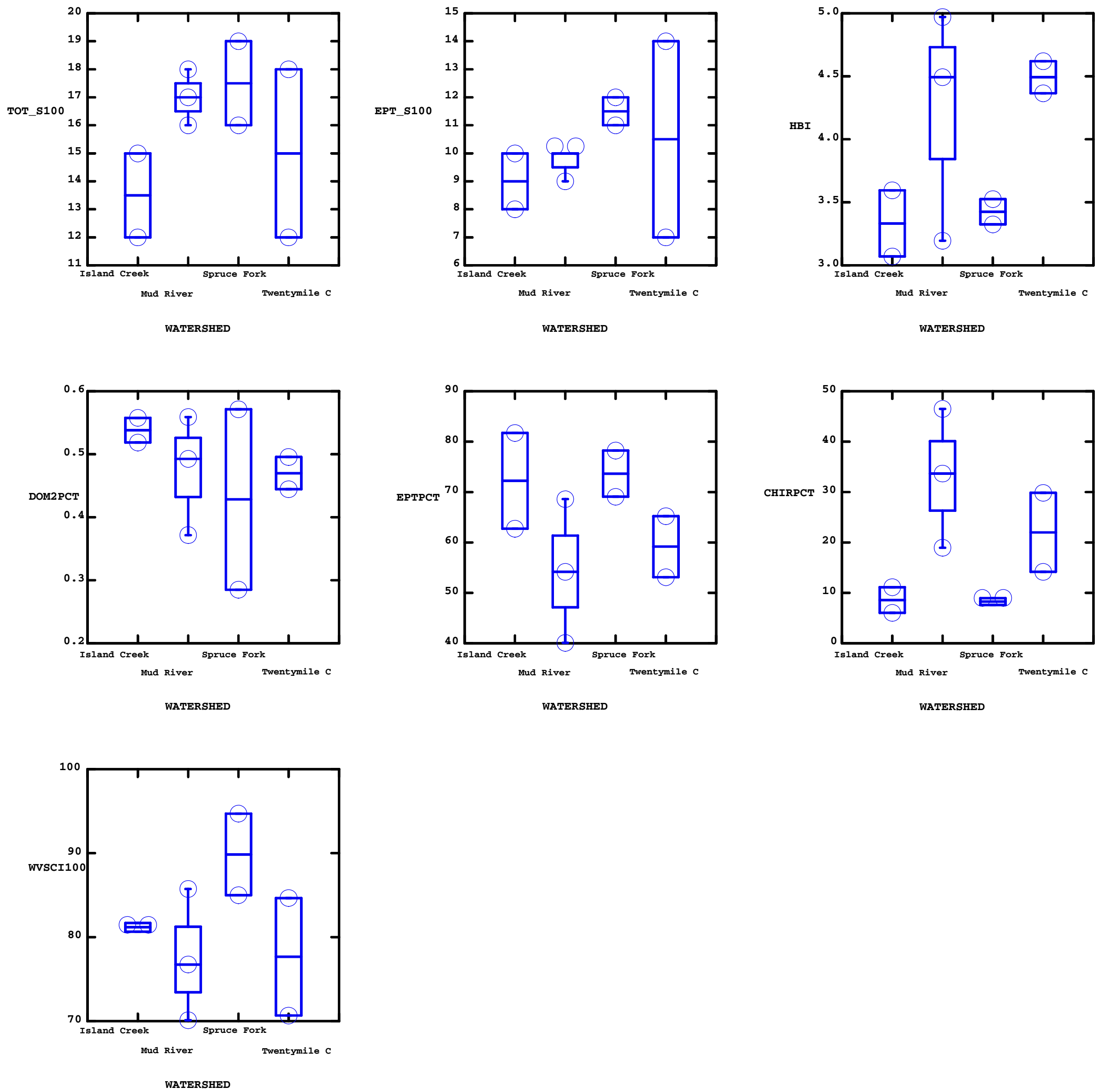

Figure C-7. Box plots of the WVSCI and its component metrics versus watershed for unmined sites in the spring 1999 season.

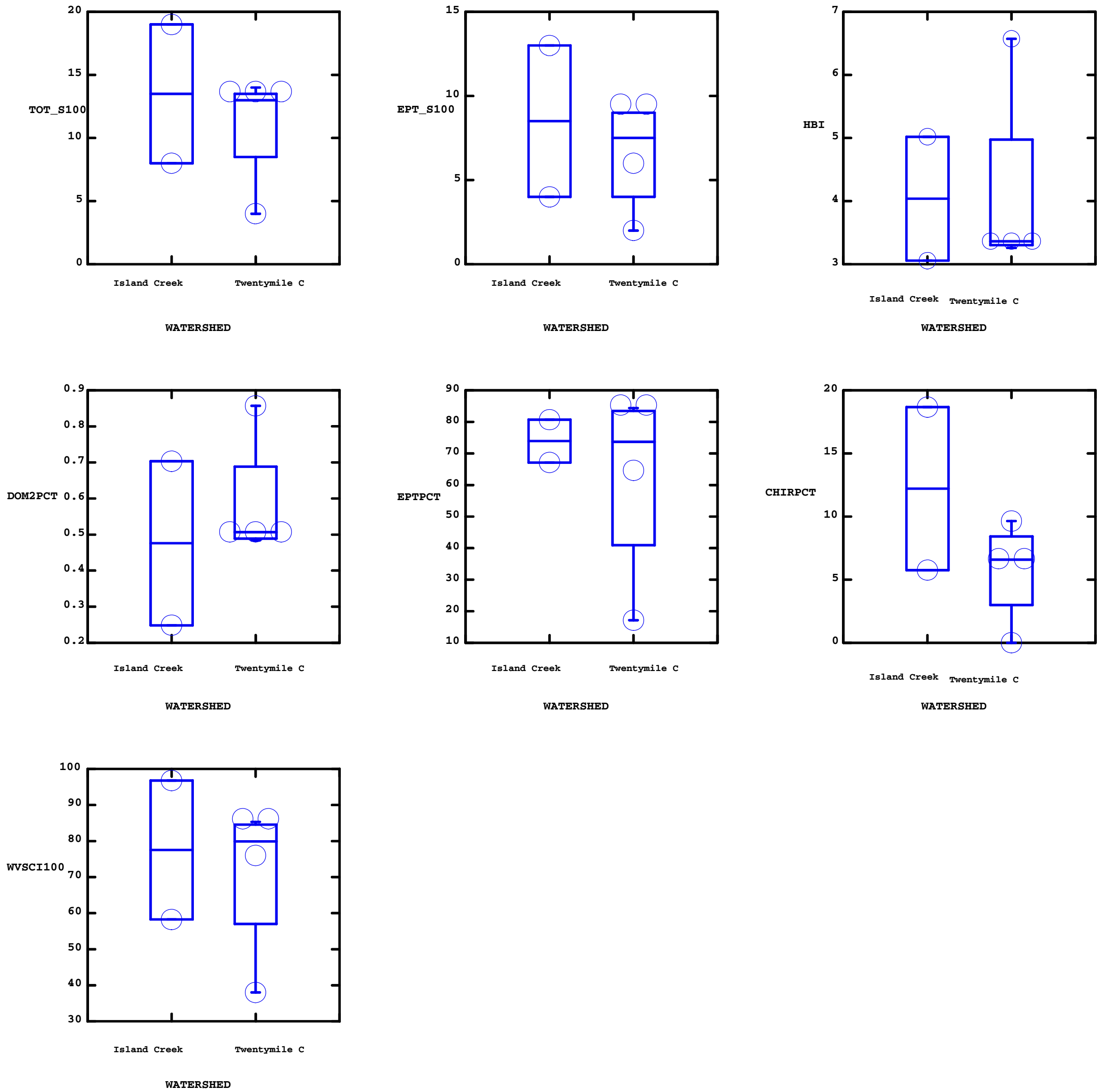

Figure C-8. Box plots of the WVSCI and its component metrics versus watershed for unmined sites in the autumn 1999 season.

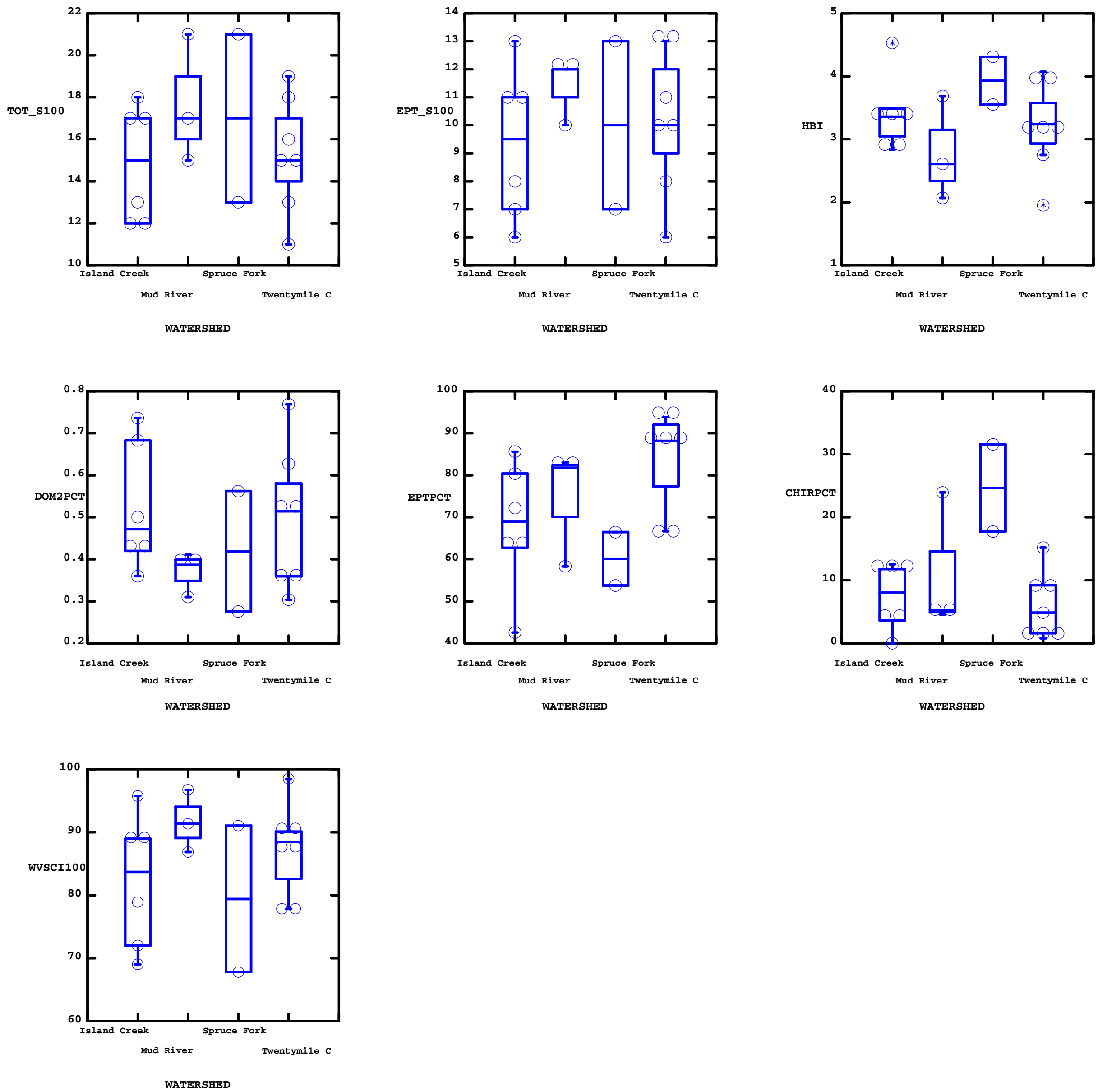

Figure C-9. Box plots of the WVSCI and its component metrics versus watershed for unmined sites in the winter 2000 season.

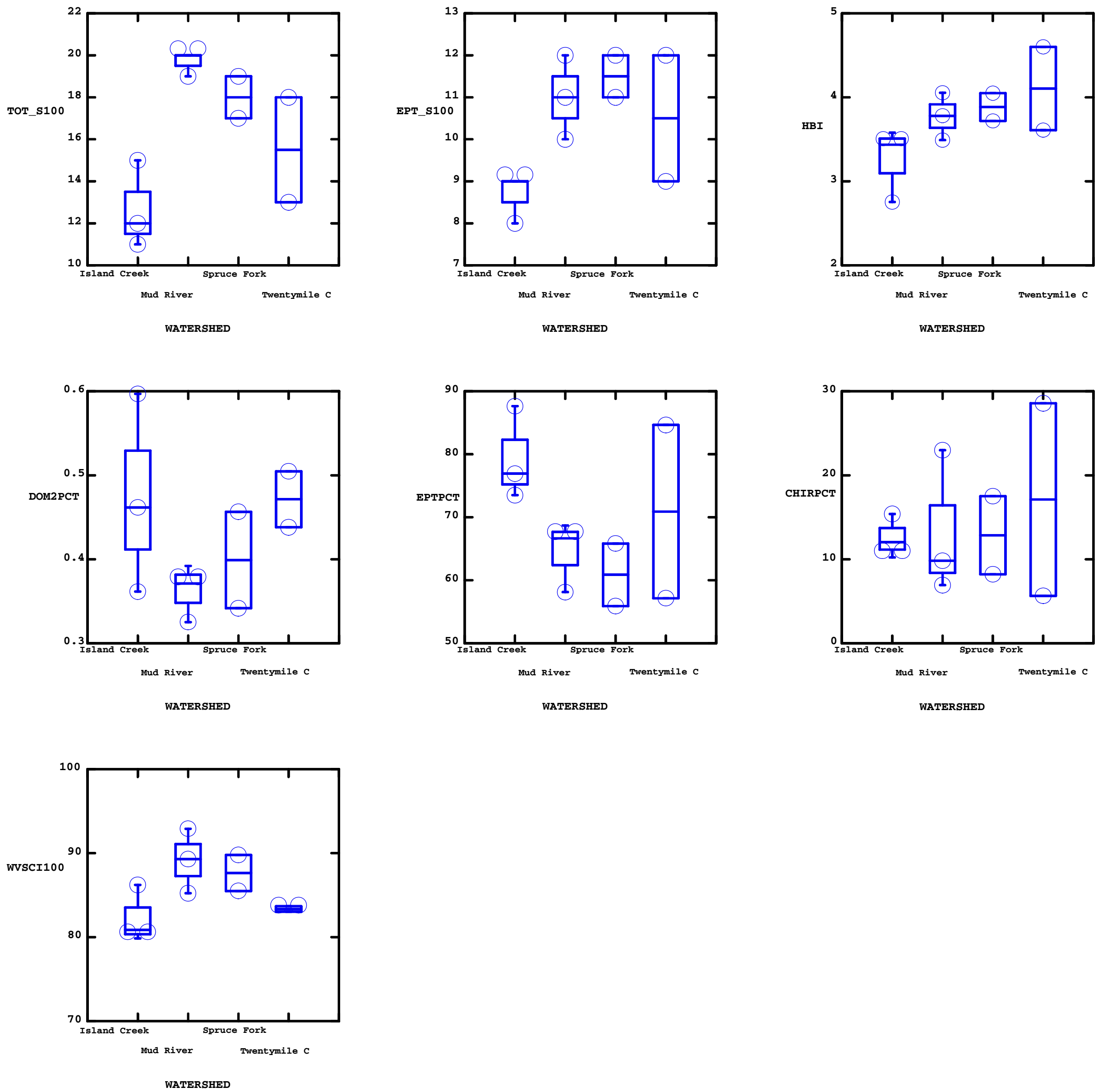

Figure C-10. Box plots of the WVSCI and its component metrics versus watershed for unmined sites in the spring 2000 season.

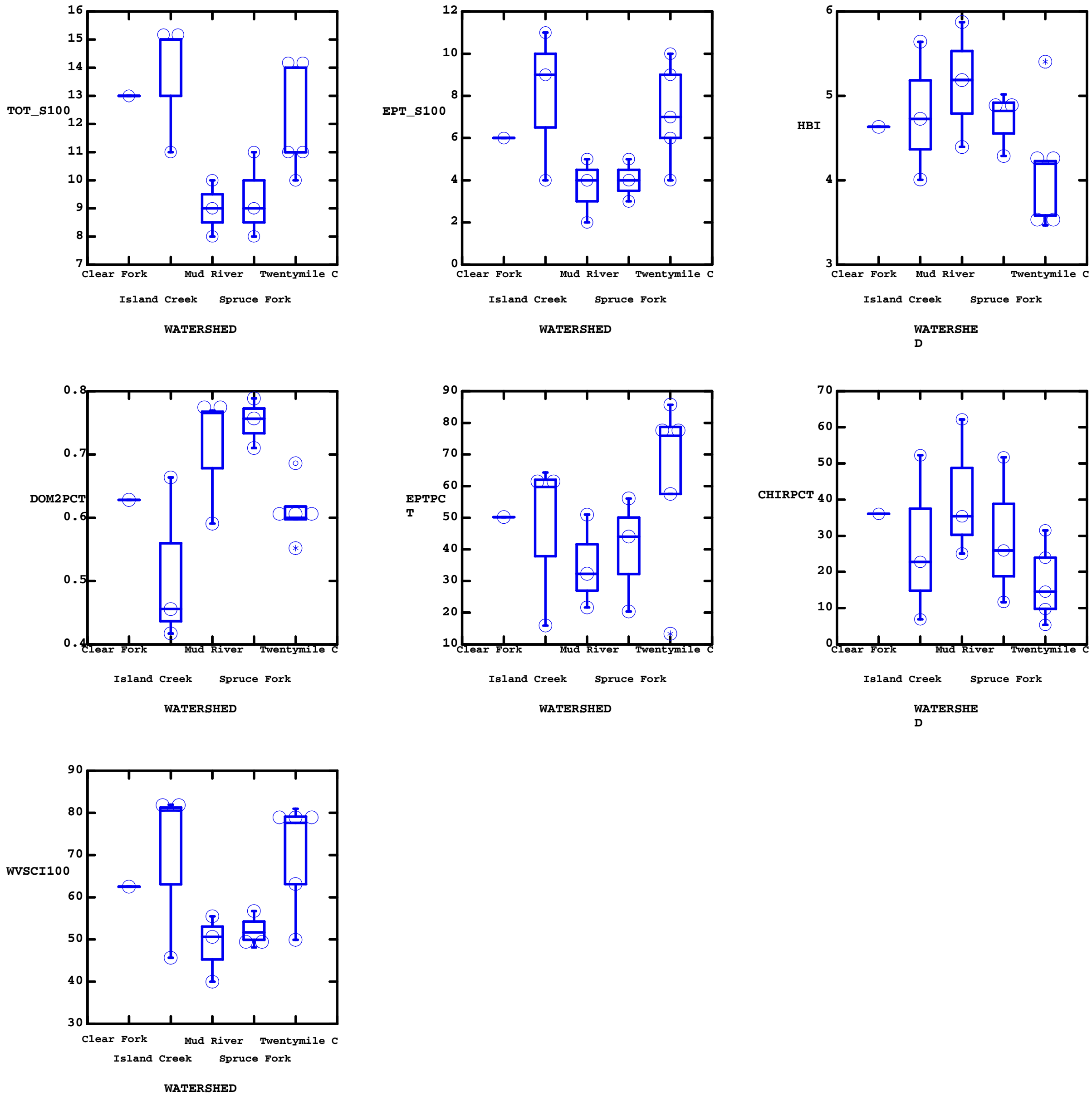

Figure C-11. Box plots of the WVSCI and its component metrics versus watershed for Filled sites in the spring 1999 season. Circles represent site scores.

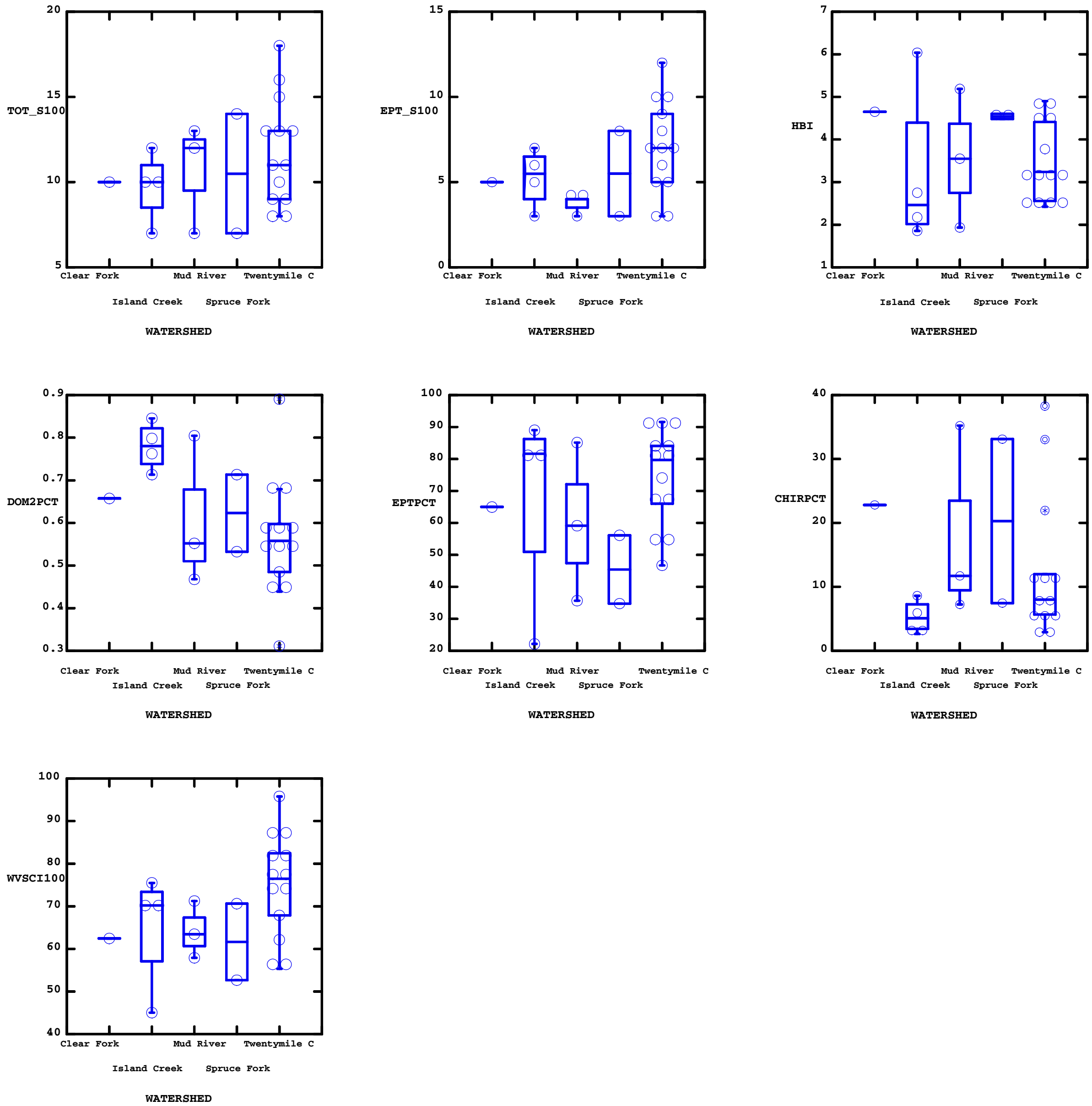

Figure C-12. Box plots of the WVSCI and its component metrics versus watershed for Filled sites in the autumn 1999 season. Circles represent site scores.

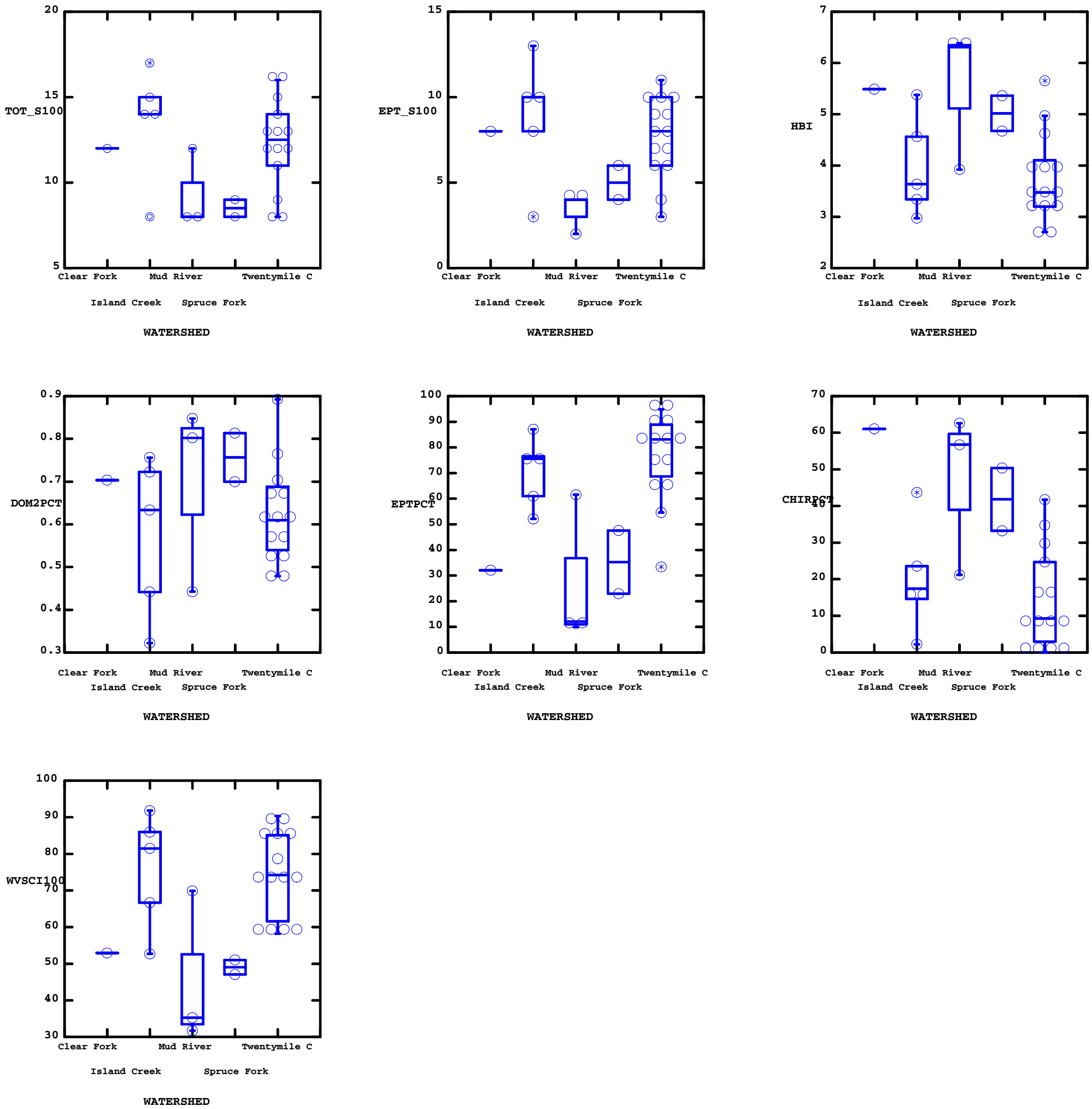

Figure C-13. Box plots of the WVSCI and its component metrics versus watershed for Filled sites in the winter 2000 season. Circles represent site scores.

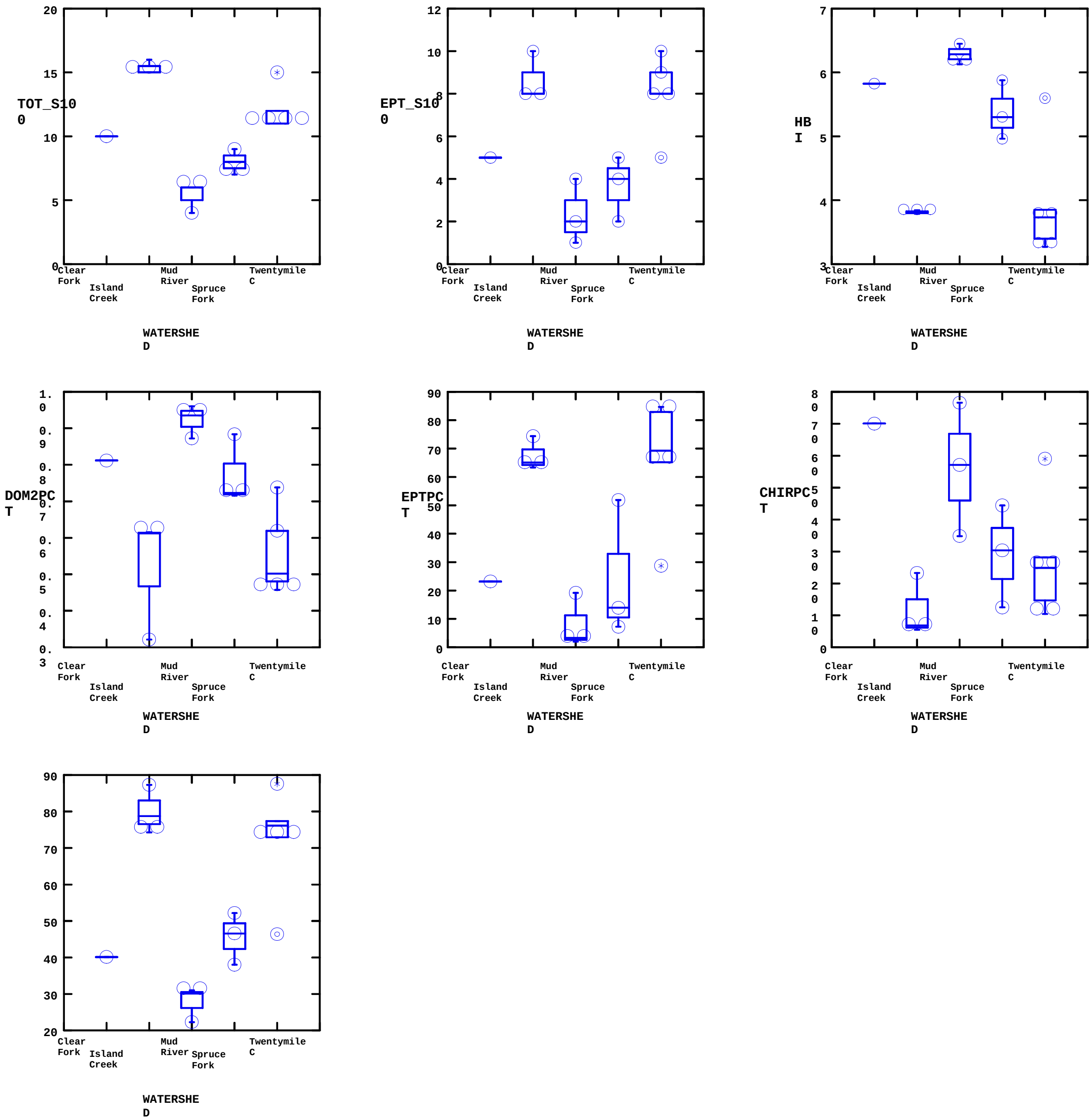

Figure C-14. Box plots of the WVSCI and its component metrics versus watershed for Filled sites in the spring 2000 season. Circles represent site scores.

APPENDIX D: SCATTER PLOTS OF THE WVSCI VERSUS KEY WATER QUALITY PARAMETERS

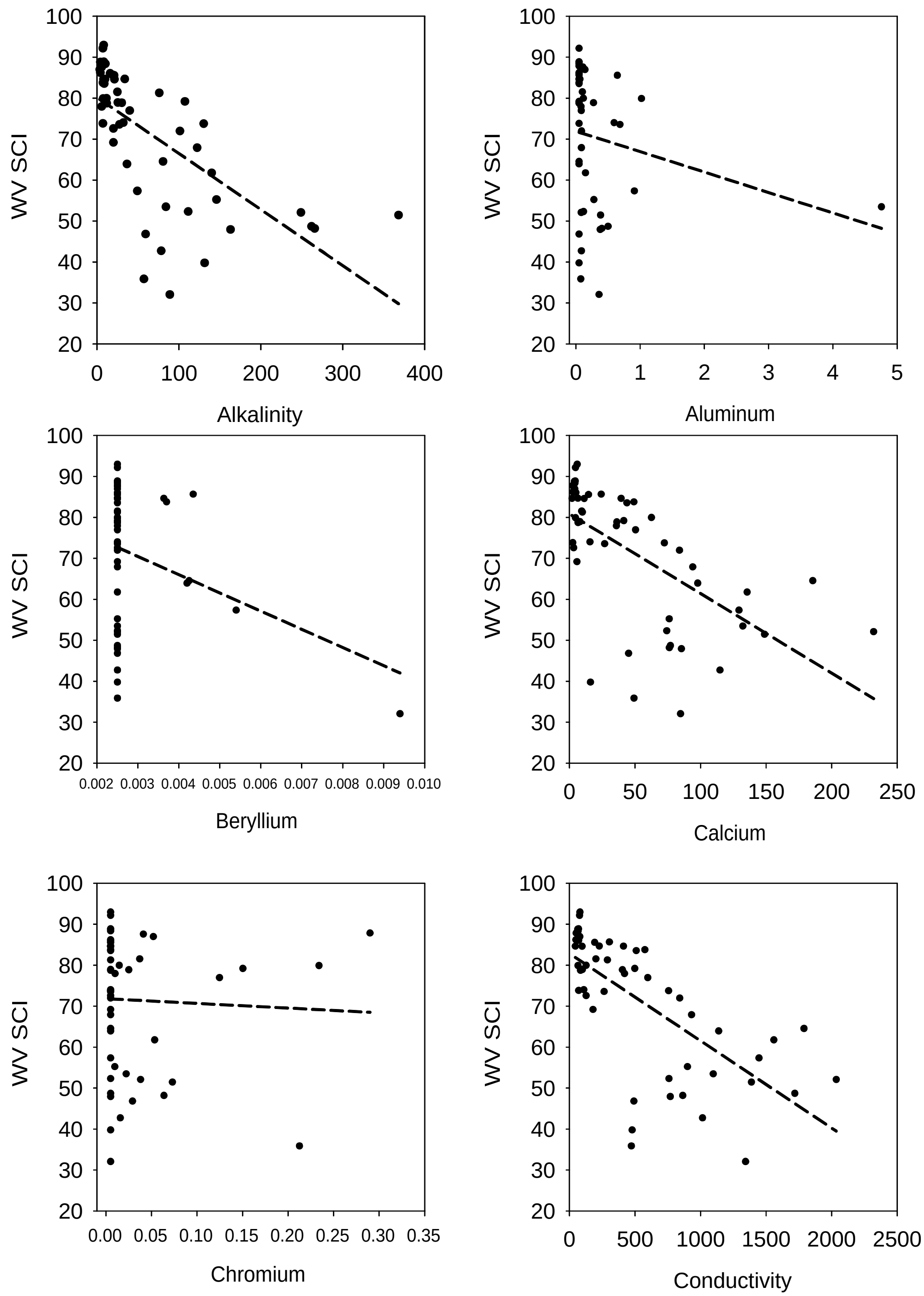

Figure D-1. The WVSCI, rarefied to 100 organisms, versus water quality parameters. Dashed line represents best fit line using linear regression.

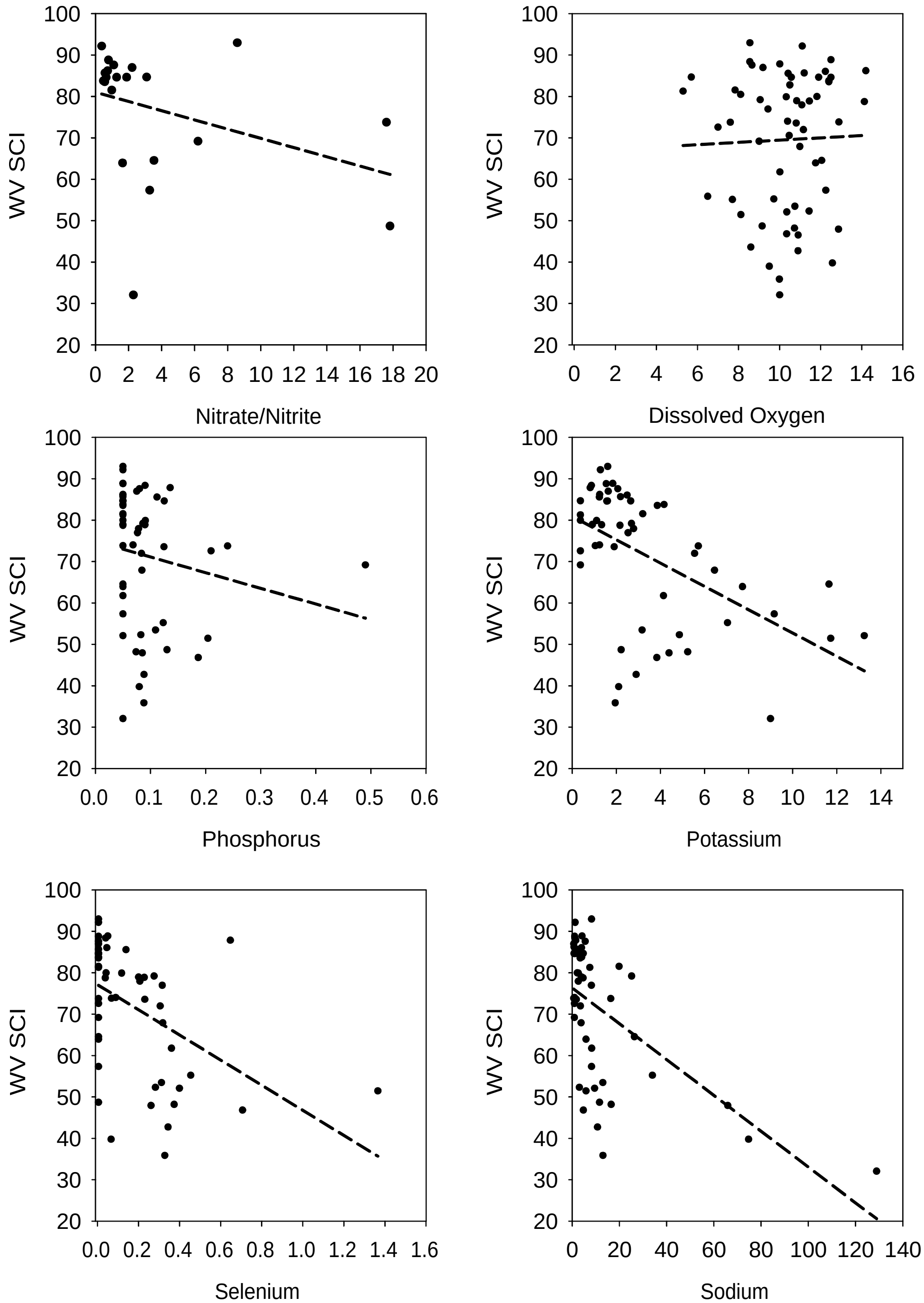

Figure D-1. Continued.

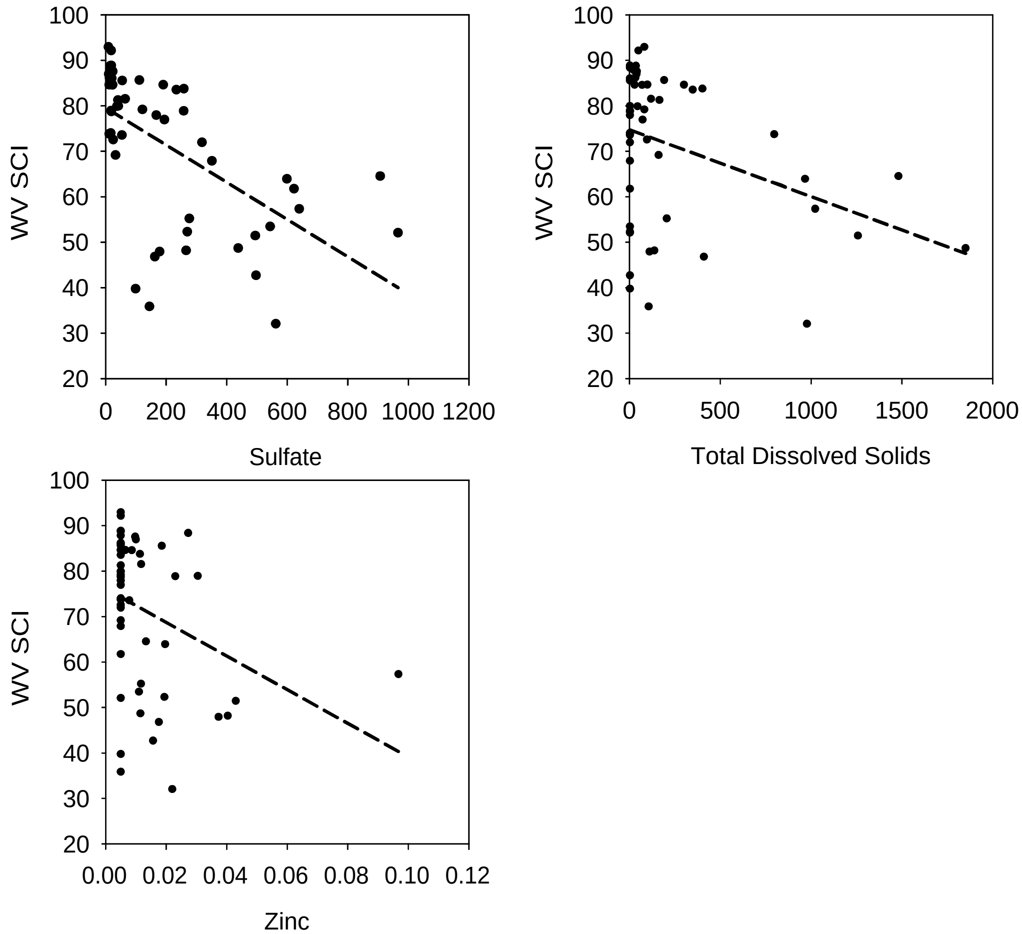

Figure D-1. Continued.

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 km^2 watershed. (McCormick, personal communication)

Richness Metric	Regression Equation	Adjustment Factor
Native Intolerant Taxa	predicted = 0.440071 + 0.515214 * Log10 (Drainage Area [km^2])	1.470
Native Cyprinidae Taxa	predicted = 0.306788 + 2.990011 * Log10 (Drainage Area [km^2])	6.287
Native Benthic Invertivores	predicted = 0.037392 + 2.620796 * Log10 (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 5th percentile of McCormick's non-reference sites; 10 points were given if the adjusted value was greater than the 50th 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 90th 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.

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 be 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).

$$E(S_n) = \sum_i \left[1 - \frac{\left((N - N_i) \frac{1}{n} \right)}{\left(\frac{N}{n} \right)} \right]$$

= 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 *i*th 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	Nemouridae	Taeniopterygidae	Nemouridae	Taeniopterygidae	Taeniopterygidae	Nemouridae	Taeniopterygidae	?
Subdominant family	Chironomidae	Chironomidae	Chironomidae	Polycentropodidae	Baetidae	Ameletidae	Nemouridae	?

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.

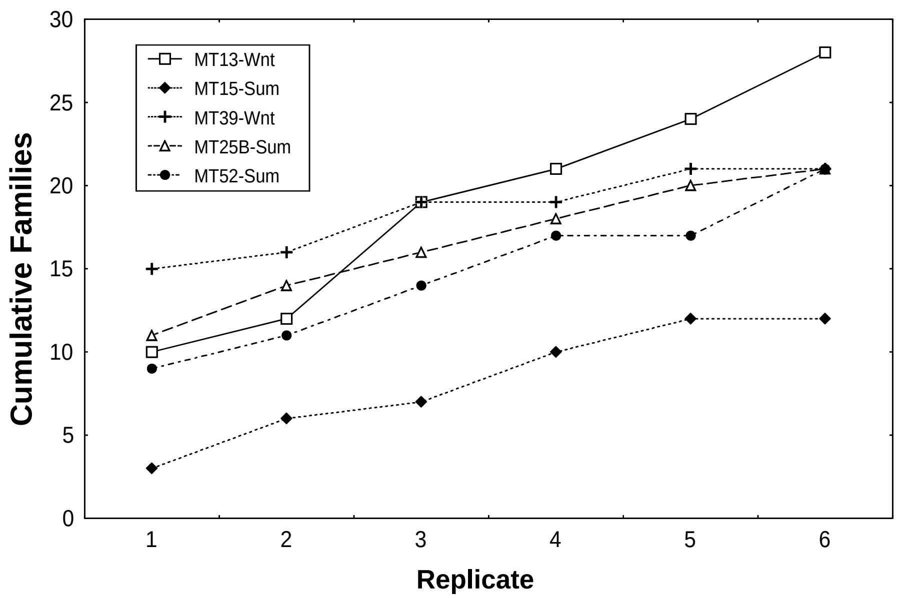

Figure E-1. Cumulative number of families identified in successive Surber samplers from 5 MTM sites.

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.

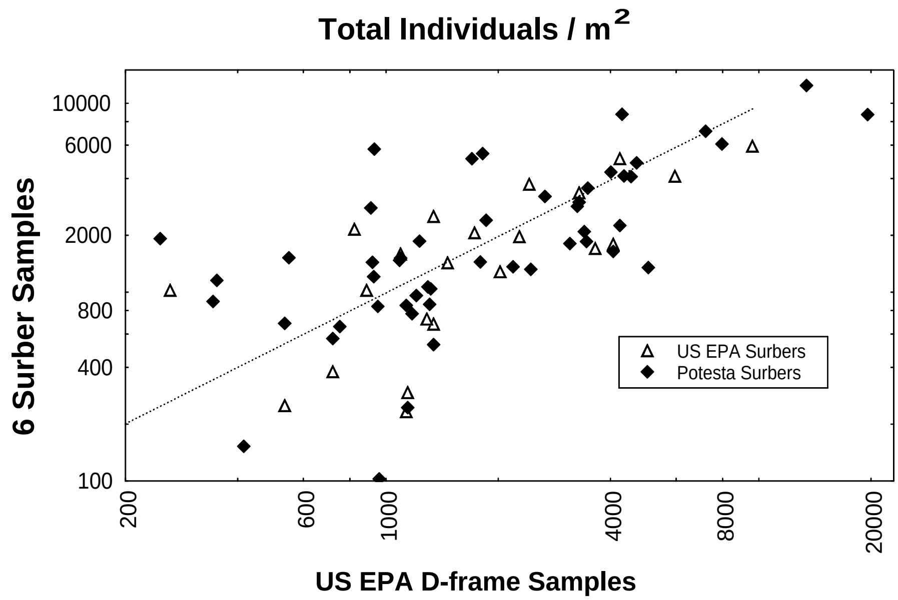

Figure E-2. Total number of individuals from 6 Surber samplers and from EPA D-frame samples. Each point represents a comparison of Surber and D-frame results from the same site at the same time. The vertical axis is the Surber results, and the horizontal axis is the D-frame results. The dotted line is 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, as a result of 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).

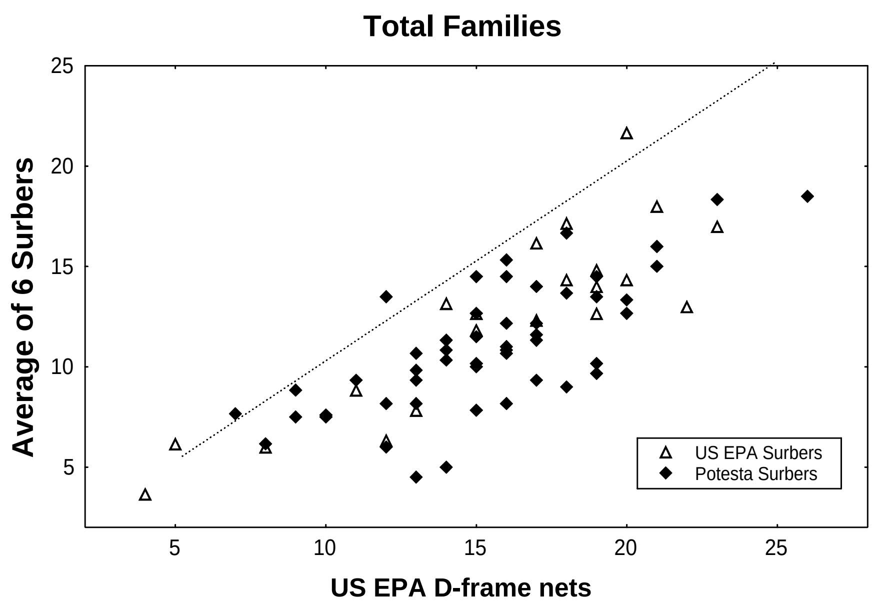

Figure E-3. Number of families per site, averaged over 6 Surbers (vertical), against total numbers from D-frame samples. See Figure E-2 caption.

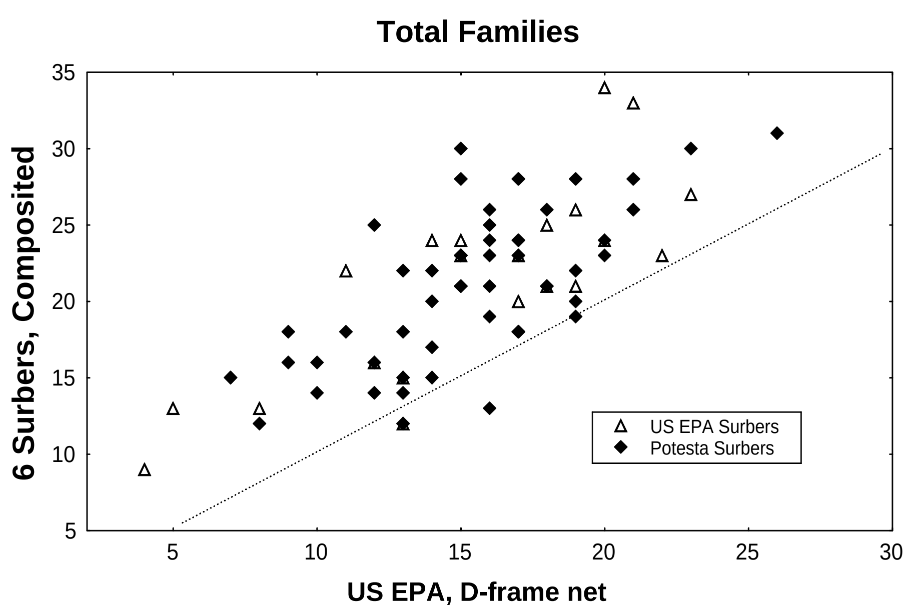

Figure E-4. Total families per site, from composite of 6 Surbers (cumulative), compared to EPA D-frame results. As in Figures E-2 and E-3.

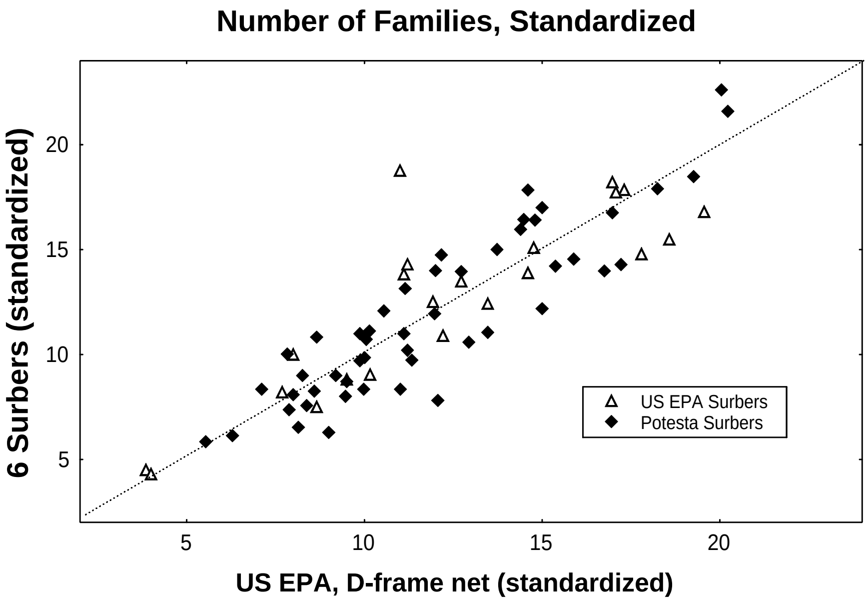

Figure E-5. Number of taxa in standardized Surber samples (vertical) compared to standardized D-frame samples (horizontal). As in Figures E-2-4.

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 1/8th of the total material (with some exceptions noted in the data); REIC to 1/4th 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 1/8th 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	score100 = 100 × (X/18),	score200 = 100 × (X/21)
EPT taxa	score100 = 100 × (X/12),	score200 = 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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AMPHIBIAN UTILIZATION OF SEDIMENT CONTROL STRUCTURES COMPARED TO A NATURAL VERNAL POOL LOCATED ON MINE PERMITTED AREAS IN SOUTHERN WEST VIRGINIA

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AMPHIBIAN UTILIZATION OF SEDIMENT CONTROL STRUCTURES COMPARED TO A NATURAL VERNAL POOL LOCATED ON MINE PERMITTED AREAS IN SOUTHERN WEST VIRGINIA

INTRODUCTION

Typically, sediment ditches and diversion ditches are constructed as part of the mining process 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 receiving streams. The larger, sediment control ponds are also generally constructed as part of the mining process 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 devised 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 which are 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.

The construction of these sediment control structures inadvertently created habitat suitable for amphibians. Fishless ponds and wetlands form important breeding habitats for amphibians native to West Virginia. Amphibians can often reach higher densities and diversity in ponds where fish predation is minimal. Natural ponds and lakes are often uncommon in the steep mountains, and amphibians readily utilize any available habitat. These man-made sediment structures and pools provide the lentic waters necessary for amphibians and reptiles as well as those benthic macroinvertebrates such as Odonates (dragonflies and damselflies) which require that type of habitat. By their construction, they add a facet to the environment which had previously not been present. Frogs can quickly colonize new wetlands because the juvenile stages disperse widely. Salamanders colonize new ponds more slowly because they do not disperse as readily as frogs. Many amphibians can be found at ponds only when they are mating or laying their eggs, or in the immature egg or larval stage, since the majority of their annual activity occurs in terrestrial habitats. Monitoring these animals away from ponds is very difficult, but since amphibians congregate at discreet breeding sites and larval stages are present for months at a time, focusing monitoring efforts on ponds is a feasible way of obtaining data on these populations and individual pond use.

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 the coal company being released from permitting regulations, and receiving back their 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 amphibian usage of these sediment control ditches which currently exist on mine permitted areas in southern West Virginia. This would add yet another facet to the studies previously conducted on these ponds including benthic sampling, water chemistry analysis, and habitat evaluations. This study compared three man-made sediment ditches to a naturally occurring vernal pool located in an unmined section of the watershed beginning approximately 3.2 stream miles from the reference pool. The sediment ditches were used instead of the deeper sediment control ponds because the ditches more closely resembled the hydrologic characteristics of the vernal pool. Several structures of various ages were studied as to their aquatic and wetland status, and to their usefulness as quality habitats for amphibians inhabiting the area.

LOCATION OF STUDY SITES

The study area is located in south-central Wayne County, in southwestern West Virginia. Samples were collected from sediment ditches 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). A naturally occurring vernal pool about 75 feet from Kiah Creek, was located 2,000 feet below the confluence of Kiah Creek with Laurel Branch, and was sampled as a reference site.

METHODS OF INVESTIGATION

At each sampled pond or sediment ditch, measurements for physical water quality were taken. Water samples were collected, and were analyzed for several parameters. Amphibian samples were collected, structure usage observations were recorded, and the habitat of the structures were 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™ Datasonde multi-parameter probe.

Water samples were collected at each of the three sediment ditches on October 08, 1999, and from the vernal pool on April 10, 2000, 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.

Amphibian Usage of Structures

Amphibian usage of the sediment control structures as well as the reference pond was evaluated by three methods as outlined in "Amphibian Monitoring Protocol - George Washington and Jefferson National Forest, Virginia" (Mitchell, 1997): 1) physical samples 2) daytime visual observations, and 3) nighttime call identification of frogs and toads.

The physical samples were conducted via D-frame nets with 500µm mesh size netting. At each sediment structure or pond, 10 replicate sweeps were conducted a minimum of 5 meters apart and included all habitat types in the pools. The contents of each sweep were then examined for amphibians, and identified.

The pools were thoroughly inspected following the sweeps. Daytime visual observations included animals that were seen at the ponds, but not captured in the dipnets. This type of sampling is especially important in locating egg masses. Lastly, each structure was re-visited after dark, and the calls of frogs and toads were used to identify the species present at each pool.

Habitat

The habitat at each of the sites was assessed emphasizing the quantity and types of vegetation present, pond/ditch slopes, surface acreage, depth, substrate composition, and composition of surrounding area (forested, open field, heavy haul traffic area, etc...).

SPECIFIC SITE LOCATIONS / PHYSICAL DESCRIPTIONS

Reference Site (vernal pool located below Kiah Creek and Laurel Branch confluence)

This station is located about 75 feet from Kiah Creek, and was formed in about 1995 (PHOTOGRAPHS 1 - 2). This age is uncertain, but thee structure is at least 5 - 10 years old. The pond is approximately 180 feet in length, and is approximately 60 feet wide, and has an area of approximately 0.25 acres. The elevation of the pond bottom is about 950 feet above sea level. The current water depth was a maximum of about 2.5 feet. The banks were very well vegetated with various trees and saplings, but shrubs and herbaceous vegetation were also present. Much of the vegetation was recently inundated. The structure is noted to completely dry up during late summer or fall, and is dependant upon heavy precipitation events. Emergent aquatic vegetation was found along the edges, and included spike rushes. The banks were not steep along the hillsides, and were noticeably stable due to their low gradient and thick vegetation. Soils were very organic and rich due to this structure being located directly in a forested floodplain, and receiving enormous amounts of detrital materials. There was a full canopy cover provided by the dense surrounding deciduous forest. The substrate was comprised mostly of detrital material over silt (TABLE 4).

Vance Branch (Rollem Fork Number 3 Surface Mine; Combination Ditch Number CD3)

This station was located on Vance Branch, and was constructed in 1999 (PHOTOGRAPHS 3 - 4). The series of three combination sediment structures are approximately 2,250 feet in length, and are approximately 41 feet wide, and have an area of approximately 2.12 acres. The approximate size of the single sediment structure sampled was 300 feet long and 30 feet wide (0.21 acres). The elevation of the structure's bottom is about 1,000 feet above sea level. The existing water depth was only about a foot, but the structure provides for 4.28 acre/feet of accumulative sediment storage. Even though the sediment structure was constructed in 1999, the banks were moderately vegetated, and this was with various grasses and clover for erosion control. Aquatic vegetation was minimal except for a small quantity of cattails. 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 1) probably due to sediments being washed into the structure easier than at older, more established ones. There was no canopy cover, and the nearest undisturbed forested area was approximately 1/4 mile away. The substrate was comprised mostly of silt and clay (TABLE 4).

Rollem Fork (Rollem Fork Number 2 Surface Mine; Sediment Ditch Number SD-3)

This station was located on Rollem Fork, and was constructed in 1997 (PHOTOGRAPHS 5 - 6). The series of three sediment control structures are approximately 900 feet in length, are approximately 40 feet wide, and have an area of approximately 0.83 acres. The approximate size of the single sediment structure sampled was 225 feet long and 25 feet wide (0.13 acres). The elevation of the structure's bottom is about 950 feet above sea level. The existing water depth was only about six inches, but the structures provide for 1.67 acre/feet of accumulative sediment storage. Even though the structure was constructed in 1997, the banks were 100% vegetated, and this was with various grasses, clover, and sedges. Aquatic vegetation was dominated by cattails which covered the pond. 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, and the closest undisturbed forested area was approximately 75 feet away. The substrate was comprised mostly of vegetated silt (TABLE 4).

Left Fork of Parker Branch (Sediment Ditch Number 6)

This station was located on the Left Fork of Parker Branch, and was constructed in 1994 (Figure 6). The series of two sediment structures are approximately 600 feet in length, are approximately 40 feet wide, and have an area of approximately 0.55 acres. The approximate size of the single sediment structure sampled was 300 feet long and 40 feet wide (0.28 acres). The elevation of the structure's bottom is about 950 feet above sea level. The existing water depth was about 5 feet, and this sediment structure provides for over 2.5 acre/feet of accumulative sediment storage. The banks were well vegetated, and this was with various grasses, clover, sedges, and goldenrod. Aquatic vegetation consisted of cattails, pondweeds (Potamogeton sp.), and water milfoil (Myriophyllum sp.) (PHOTOGRAPHS 7 - 8). There was a fairly heavy algae growth which was presumed to be a result of the higher pH level of this structure (TABLE 1). 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, and the nearest undisturbed forested area was approximately 1/3 mile away. The substrate was comprised mostly of clay and silt (TABLE 4).

PHYSICAL AND CHEMICAL WATER QUALITY ANALYSIS

Physical and chemical water quality was analyzed at each of the pool and sediment control structures sampled on Vance Branch, Rollem Fork, and the Left Fork of Parker Branch. The physical and chemical water quality results are presented in TABLE 1. Many of the sediment structures had large differences between some of the parameters. For instance, the pH on Rollem Fork's sediment ditch was slightly low with a pH of 6.37, whereas the pH for the sediment ditch on Vance Branch was high (probably because of the use of hydrated lime in the vicinity) with a pH of 10.44. Most of the chemical values such as dissolved solids, hardness, sulfates, alkalinity, and most metals were considered fairly high. Although in a previous study, several of these values were considered limiting to the benthic macroinvertebrate communities, it should be remembered that one of the primary purposes of the ponds and sediment control structures is to reduce the high levels of solids and metals by settling them out prior to their reaching the downstream portions of the receiving streams.

HABITAT ASSESSMENT

Several habitat measurements were determined (TABLE 4) 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 some aquatic organisms 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. For pond and wetland type habitats, the ability of the substrate to support vegetation is important.

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 aquatic 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.

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. An estimate is obtained by visually determining the dominant vegetation type covering the pond bottom, bank, and top of bank. Riparian vegetation dominated by shrubs and trees provides the CPOM source in allochthonous systems.

HABITAT RESULTS

Reference Pool (vernal pool located on Kiah Creek below confluence with Laurel Branch)

This naturally occurring vernal pool had a surface area of 0.25 acres, was 180 feet long by 60 feet wide. Although it had a fairly recent origination date (no later than 1995), the banks were very well vegetated, and with trees, saplings, shrubs, and herbaceous plants due to the dense surrounding forest. The substrate was silt covered with a dense layer of leaves and other detrital matter. This structure has very good wetland potential as it stays wet except during extreme periods of drought. The dense surrounding forest provides food inputs for benthic organisms, shade, and is close enough for the animals which head to the pond at night such as frogs and toads. However, because it is cut off from Kiah Creek except during periods of very heavy precipitation, it will most likely not perform well as a water filtration structure, since water does not regularly flow through the pond.

Vance Branch (Rollem Fork Number 3 Surface Mine; Combination Ditch Number CD3)

This sediment control structure had a surface area of 0.21 acres, was 300 feet long by 30 feet wide, and had an accumulative sediment storage potential of 4.28 acre/feet (TABLE 4). 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 also do very well as a water filtration structure. However, because it is separated from forested areas by about a 1/4 mile, animals such as salamanders may be restricted from using the pond.

Rollem Fork (Rollem Fork Number 2 Surface Mine; Sediment Ditch Number SD-3)

This sediment control structure had a surface area of 0.13 acres, was 225 feet long by 25 feet wide, and had an accumulative sediment storage potential of 1.67 acre/feet (TABLE 4). 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 silt, and the pond was completely covered with cattails. 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. This pond is considerably closer (approximately 75 feet) to undisturbed forested areas than either of the other two sediment control structures.

Left Fork of Parker Branch (Sediment Ditch Number 6)

This sediment control structure had a surface area of 0.28 acres, was 300 feet long by 40 feet wide, and had an accumulative sediment storage potential of at least 2.5 acre/feet (TABLE 4). 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. However, because this sediment pond is also separated from the woods by a considerable distance (approximately 1/3 mile), animals such as salamanders may be restricted from using the pond.

AMPHIBIAN RESULTS

Reference Pool (vernal pool located on Kiah Creek below confluence with Laurel Branch)

Adult and larvae spring peepers *Pseudacris crucifer*, adult green frogs *Rana clamitans*, and mountain chorus frogs *Pseudacris brachyphona*, and spotted salamander *Ambystoma maculatus* egg masses were observed at the reference pond (see TABLE 5). This is a typical species assemblage for a woodland vernal pool in the mountains of West Virginia.

Vance Branch (Rollem Fork Number 3 Surface Mine; Combination Ditch Number CD3)

Adult and larvae spring peepers were observed at the 14 month old Vance Branch pond. Adult mountain chorus frogs were heard calling nearby. Single eggs were found attached to the underside of vegetation, possibly those of red-spotted newts *Notophthalmus viridescens*, although no adults were observed (see TABLE 5).

Rollem Fork (Rollem Fork Number 2 Surface Mine; Sediment Ditch Number SD-3)

Adult and larvae spring peepers, adult and egg-stage American toads *Bufo americanus*, adult and egg-stage red spotted newts, and spotted salamander egg masses were observed at the 2-3 year old Rollem Fork pond (see TABLE 5).

Left Fork of Parker Branch (Sediment Ditch Number 6)

Adult red spotted newts, and adult and egg stage green frogs were observed at the 4-5 year old Left Fork of Parker Branch pond (see TABLE 5).

DISCUSSION

All of the ponds or pools studied had different amphibian assemblages (see TABLE 5). The reference pool and Rollem Fork pond had the highest diversity with four amphibian species each. Only spring peepers were found at all of the ponds surveyed. This result is not unexpected since spring peepers are the most highly mobile and abundant of all the species encountered. They were most likely the first specie to colonize the newly created ponds.

Red spotted newts were found at Vance Branch pond, Rollem Fork pond, and Left Fork of Parker pond, but not at the reference pond. Since these animals are very mobile as juveniles, and spend up to seven years wandering the forest before going to ponds to breed, it is expected that they too would readily colonize new ponds. The absence of newts from the reference pond could be a function of the large mass of detrital material covering the pond bottom, making viewing and capture of the newts difficult, or the major influence of the nearby stream, since red spotted newts are not normally stream dwelling creatures. In addition, although not a primary objective of the study, it was noted that caddisflies, odonates, mayflies, and waterbugs were also absent from the reference pool, whereas they were abundant in the sediment control structures (TABLE 5). One reason for this observation is that the reference pool is vernal, and therefore, is dry for part of the year. Many of the above mentioned insects have 2-year life cycles, and consequently, require water year round.

Another notable difference between the pond amphibians is the much greater abundance of spring peeper tadpoles found at the reference site (see TABLE 6). Not only were there many more found at that pond, but they were much larger and further along in their development. One would think this would be a function of pond age, however, no spring peeper tadpoles were found in the oldest of the constructed ponds, Left Fork of Parker pond. It may possibly be related to other factors such as amount of vegetation, temperature, chemistry, and/or predators. Amphibians are known to be relatively tolerant to low pH, but less tolerant to high pH conditions. As shown in TABLE 1, the pH of the Left Fork of Parker Branch and the Vance Branch sediment control structures was 8.18 and 10.44, respectively, and these two structures contained the least number of spring peepers.

From the data collected for this study, a critical aspect in the colonizing of these ponds by amphibians is the proximity of undisturbed, or wooded areas. Rollem Fork pond and the reference pond were the only two to contain egg masses of the spotted salamander. This animal is highly terrestrial and spends the majority of the year underground in the forest. Although aquatic habitat is essential to reproduction, mole salamanders, such as the spotted salamander, are very susceptible to predation or dessication when traveling long distances without cover, and are reluctant to do so. Therefore, the closeness to forested areas and robust populations, are likely the determining factors in spotted salamander use of created ponds, as well as use by other amphibians.

CONCLUSIONS

All the ponds sampled were shown to be utilized by amphibians for a necessary part of their life stage. Overall, the sediment control ditches sampled were represented by amphibians that would be expected of ponds that age. The amount of vegetation and distance to forested areas seemed to be key factors in the ponds ability to recruit nearby amphibians.

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 lentic aquatic habitat (which amphibians require) 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 and useful habitat feature, and provide an additional facet to the aquatic, semi-aquatic, and terrestrial wildlife currently found in area.

TABLE 1. Physical water-quality variables from the Reference Pool, 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 the Left Fork of Parker Branch (Sediment Ditch Number 6), 10 April 2000.

PARAMETER	Reference Pool (1995)	Vance Branch (1999)	Rollem Fork (1997)	Left Fork Parker (1991)
Temperature (°C)	8.08	11.51	17.05	16.14
Dissolved Oxygen (mg/l)	4.49	12.53	9.20	9.54
pH (SU)	6.37	10.44*	6.90	8.18
Conductivity (µmhos)	13.2	456.9	695.9	205.1

* = Most likely a result of hydrated lime usage in the vicinity.

TABLE 2. Chemical water-quality variables from the Reference Pool (sample collected 10 April 2000), 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 the Left Fork of Parker Branch (Sediment Ditch Number 6), 10 April 2000.

PARAMETER	Reference Pool (1995)	Vance Branch (1999)	Rollem Fork (1997)	Left Fork Parker (1991)
BOD (mg/l)	<2	<2	<2	<2
TDS (mg/l)	26	302	288	84
TSS (mg/l)	<1	172	16	3
DOC (mg/l)	2.4	NA	NA	NA
Fecal Coliform	NA	>270	49	14
Hardness (mg/l)	15.9	285	182	71.0
Alkalinity (mg/l)	11.4	39.2	5.8	67.1
Total Acidity (mg/l)	<1.0	<1.0	13.2	<1.0
Chlorides (mg/l)	1.3	<1.0	1.3	1.2
Sulfates (mg/l)	10.2	243	210	15.8
Aluminum (mg/l)	0.156	0.714	0.491	0.109
Antimony (mg/l)	<0.001	<0.001	<0.001	<0.001
Arsenic (mg/l)	<0.002	0.002	0.002	<0.002
Barium (mg/l)	ND	0.023	0.048	0.034
Beryllium (mg/l)	<0.001	<0.001	<0.001	<0.001
Cadmium (mg/l)	<0.0003	<0.0003	<0.0003	<0.0003
Calcium (mg/l)	2.94	71.6	43.0	17.7
Chromium (mg/l)	<0.001	<0.001	<0.001	<0.001
Copper (mg/l)	<0.005	<0.005	<0.005	<0.005
Total Iron (mg/l)	0.356	0.422	1.28	0.132
Lead (mg/l)	<0.001	<0.001	<0.001	<0.001
Magnesium (mg/l)	2.08	25.8	18.2	6.50
Manganese (mg/l)	0.025	1.44	3.94	0.017
Mercury (mg/l)	<0.0002	<0.0002	<0.0002	<0.0002
Nickel (mg/l)	<0.020	<0.020	0.036	<0.020
Phosphorous (mg/l)	<0.05	NA	NA	NA
Selenium (mg/l)	<0.003	<0.003	0.003	<0.003
Silver (mg/l)	<0.004	<0.004	<0.004	<0.004
Sodium (mg/l)	1.41	1.12	1.08	0.690
Thallium (mg/l)	<0.001	<0.001	<0.001	<0.001

Zinc (mg/l)	0.010	0.023	0.074	<0.002

TABLE 3. Habitat descriptions for the individual sediment control structures located at the Pen Coal Corporation, 10 April 2000.

	Reference Pool (1995)	Vance Branch (1999)	Rollem Fork (1997)	Left Fork (1994)
Pond/Ditch Surface Acreage				
	0.25	0.21	0.13	0.28
Length x Width (feet)				
	180 x 60	300 x 30	225 x 25	300 x 40
Total (all ponds in series) Accumulative Sediment Storage (Acre/feet)				
	NA	4.28	1.67	>2.58
Bottom Substrate Type				
	leaves over silt	silty, clay	vegetated silt	clay, silty
Bank Stability				
	stable	moderately stable	stable	stable
Bank Vegetation Stability				
	100% vegetated with trees, shrubs, herbaceous plants	moderately vegetated (soils not fully developed)	100% vegetated	100% vegetated

TABLE 3. CONTINUED.

Vegetation Types				
	heavily vegetated with trees, shrubs, herbaceous plants, and submerged and emergent aquatics (forested pond)	grasses (terrestrial), some aquatic vegetation	grasses, shrubs, herbaceous plants, filamentous algae, submerged & emergent aquatics	grasses, shrubs, herbaceous plants, filamentous algae, submerged & emergent aquatics
Organic Input Sources				
	mostly allochthonous, but also autochthonous	autochthonous	mostly autochthonous	autochthonous
Pond/Ditch Cover				
	full cover	open	some	open

TABLE 4. Summary of amphibians surveyed from the Reference Pool, 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 the Left Fork of Parker Branch (Sediment Ditch Number 6), 10 April, 2000.

	POOL			
	Reference Pool	Vance Branch	Rollem Fork	Left Fork Parker
Red-spotted newt *Notophthalmus viridescens*		E	A, E	A
Spring Peeper *Pseudacris crucifer*	A, L	A, L	A, L	A
Spotted salamander *Ambystoma maculatus*	E (22)		E (3)	
Eastern American Toad *Bufo americanus*			A, E	
Mountain Chorus Frog *Pseudacris brachyphona*	A	A		
Green Frog *Rana clamitans*	A			A, E (4)
Total number of species	4	3	4	3

A = Adult
L = Larvae
E = Egg Masses (number counted)

TABLE 5. Total number of amphibians physically collected per pool (all 10 D-Frame sweeps combined) from the Reference Pool, 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 the Left Fork of Parker Branch (Sediment Ditch Number 6), 10 April 2000.

	POOL			
	Reference Pool	Vance Branch	Rollem Fork	Left Fork Parker
Red-spotted newt adults *Notophthalmus viridescens*			2	
Spring Peeper tadpoles *Pseudacris crucifer*	379	49	1	
<u>Other organisms collected</u>:				
Crayfish	1			
Earthworms	5			
Isopods	many			
Midges	many	many	many	many
Caddisflies				many
Odonates		many	many	many
Baetidae mayflies		many	many	
Hemiptera (water bugs)		many	many	many

TABLE 6. Daytime visual observation of amphibians from the Reference Pool, 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 the Left Fork of Parker Branch (Sediment Ditch Number 6), 08 October 1999.

	POOL			
	Reference Pool	Vance Branch	Rollem Fork	Left Fork Parker
Red-spotted newt *Notophthalmus viridescens*			A, E	A
Spring Peeper *Pseudacris crucifer*	L	L	L	
Spotted salamander *Ambystoma maculatus*	E (22)		E (3)	
Eastern American Toads *Bufo americanus*			E	
Green Frogs *Rana clamitans*				A, E (4)

A = Adult
L = Larvae
E = Egg Masses (number counted)

TABLE 7. List of amphibians identified from nighttime calls from the Reference Pool, 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 the Left Fork of Parker Branch (Sediment Ditch Number 6), 08 October 1999.

	POOL			
	Reference Pool	Vance Branch	Rollem Fork	Left Fork Parker
Northern Spring Peepers *Pseudacris crucifer*	many	many	many	many
Green Frogs *Rana clamitans*	several			
Mountain Chorus Frogs *Pseudacris brachyphona*	several	few		
Eastern American Toads *Bufo americanus*			few	

APPENDIX A

PHOTOGRAPH 1. Reference Site (Vernal pool located below Kiah Creek and Laurel Branch confluence).

PHOTOGRAPH 2. Reference Site (Vernal pool located below Kiah Creek and Laurel Branch confluence).

PHOTOGRAPH 3. Vance Branch (Rollem Fork Number 3 Surface Mine; Combination Ditch Number CD3).

PHOTOGRAPH 4. Vance Branch (Rollem Fork Number 3 Surface Mine; Combination Ditch Number CD3).

PHOTOGRAPH 5. Rollem Fork (Rollem Fork Number 2 Surface Mine; Sediment Ditch Number SD-3).

PHOTOGRAPH 6. Rollem Fork (Rollem Fork Number 2 Surface Mine; Sediment Ditch Number SD-3).

PHOTOGRAPH 7. Left Fork of Parker Branch (Sediment Ditch Number 6).

PHOTOGRAPH 8. Left Fork of Parker Branch (Sediment Ditch Number 6).

PHOTOGRAPH 9. Spring peeper *Pseudacris crucifer* tadpoles.

PHOTOGRAPH 10. Red-spotted newt *Notophthalmus viridescens*.

PHOTOGRAPH 11. Spotted salamander *Ambystoma maculatus* egg masses.

PHOTOGRAPH 12. Green Frog *Rana clamitans* egg masses.

PHOTOGRAPH 13. Eastern American Toad *Bufo americanus* egg masses.

“A History of the Benthic Macroinvertebrate and Water Chemistry Studies of two Long-term Monitoring Stations on Trough Fork” Conducted for Pen Coal by R.E.I. Consultants, report dated 20 June 2000.

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451975

A HISTORY OF THE BENTHIC MACROINVERTEBRATE AND WATER CHEMISTRY STUDIES OF TWO LONG-TERM MONITORING STATIONS ON TROUGH FORK

Conducted For:

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June 20, 2000

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A HISTORY OF THE BENTHIC MACROINVERTEBRATE AND WATER CHEMISTRY STUDIES OF TWO LONG-TERM MONITORING STATIONS ON TROUGH FORK

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, a tributary of East Lynn Lake.

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 which involved contour mining and point removal with valley fill construction associated with the 5-Block Seam. 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 Lynn Lake.

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.

Since 1995, Pen Coal Corporation has continued to increase the number of monitoring points, and has recently added intensive macroinvertebrate and fish habitat evaluations, as well as fisheries sampling, at many of their locations. Also, benthic macroinvertebrate biomass data has been examined for these two long-term monitoring points on Trough Fork. Currently, Pen Coal is monitoring 38 sites on 11 streams, bi-yearly for benthic macroinvertebrates, as well as several sediment control structures for benthic macroinvertebrates, water chemistry, and amphibians.

SURFACE IMPACTS

Trough Fork is a first-order stream which has a watershed of approximately 2,882 acres. Currently permitted 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 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 equates to about 44% of the intermittent tributaries of Trough Fork. Only one of these individual tributaries, Vance Branch, exceeds 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 re-graded land. This land will then be re-vegetated with various grasses, legumes, shrubs, and trees to enhance wildlife habitat. This scenario will replace the pre-mining site which originally consisted of 580 acres of unmanaged forestland and 19,800 linear feet of intermittent streams.

STATEMENT OF PURPOSE

The purpose of this paper is to identify trends in the benthic macroinvertebrate and water chemistry data which Pen Coal Corporation has collected at two long-term sites on Trough Fork (FIGURE 1) between 1995 and 2000. In addition, these data need to be shared with the coal mining industry and other interested parties, due to recent concerns over the mountaintop mining issues.

METHODS OF INVESTIGATION

A modified EPA Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers (EPA 841-B-99-002) as well as methods outlined in "Interim Chemical/Biological Monitoring Protocol For Coal Mining Permit Applications" (January 19, 2000, US EPA, Region III) and the "Programmatic Environmental Impact Statement (A Survey of the Condition of Streams in the Primary Region of Mountain Top Removal/ Valley Fill Coal Mining" - March 1999, US EPA, Region III) were followed in the collection of the benthic macroinvertebrate specimens, water chemistry, and habitat evaluations. Since 1995, measurements for flow, physical water quality, and chemical water quality have been collected in April and October at an upstream and a downstream stations on Trough Fork. Benthic macroinvertebrate samples were also collected since October 1995, and the physical habitat was evaluated and since April 1999. Fisheries evaluations have been added in the Spring 2000 sampling regime, as well as substrate characterization and geomorphological characteristics. The individual methodologies are described below.

Physical Water Quality

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

Water Chemistry

Water chemistry samples were collected at both stations and returned to R.E.I. Consultants, Incorporated for processing. Parameters analyzed included acidity, alkalinity, total hardness, fecal coliform, nitrate/ nitrite, sulfate, chloride, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), dissolved organic carbon, total phosphorous, total aluminum, dissolved aluminum, antimony, arsenic, beryllium, cadmium, calcium, chromium, copper, total iron, dissolved iron, lead, total manganese, dissolved manganese, magnesium, mercury, nickel, selenium, sodium, thallium, and zinc.

Benthic Macroinvertebrates

A modified EPA Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers (EPA 841-B-99-002) as well as methods outlined in "Interim Chemical/Biological Monitoring Protocol For Coal Mining Permit Applications" (January 19, 2000, US EPA, Region III) and the "Programmatic Environmental Impact Statement (A Survey of the Condition of Streams in the Primary Region of Mountain Top Removal/ Valley Fill Coal Mining" - March 1999, US EPA, Region III) were followed in the collection of the benthic macroinvertebrate specimens. At both stations, macroinvertebrate collections were made via a 0.1-m^2 Ellis-Rutter™ Portable Invertebrate Box Sampler (PIBS) and a kick-net (1-m^2 area) sampler. Both samplers were fitted with a 500-μm mesh size net. Three quantitative replicate PIBS samples were collected in a riffle area, and a semi-quantitative kick-net sample was colleted from a riffle/run area. Samples were placed in 1-liter plastic containers, preserved in 35% formalin, and returned to the laboratory for processing. Samples were then picked under microscope 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.

Benthic Macroinvertebrate Biomass Analysis

The individual PIBS and kick-net samples were resorted and any non-insects such as crayfish, amphipods, and isopods were removed. The macroinvertebrates from the individual samples were dried to constant weight at 100°C. Biomass from individual samples was calculated and estimates were extrapolated to an area of 1-m^2, and averaged to estimate station biomass. Station biomass for the two seasons was then plotted against time for both stations. Other biomass comparisons were also examined.

PHYSICAL AND CHEMICAL WATER QUALITY ANALYSIS

Physical and chemical water quality was analyzed in April and October at the two stations on Trough Fork beginning in October 1995 (TABLES 1A and 1B). October flow has remained relatively constant at both the upstream (BM-005) and the downstream (BM-006) stations, since mining activities began in 1996 (TABLE 1A). Likewise, pH has remained nearly neutral at both the upstream and downstream stations on Trough Fork. However, the pH has became more basic at the downstream site since mining activities began in 1996 (pre-mining downstream pH 6.08). Although Total Suspended Solids (TSS) has not changed since 1995 at either location, Total Dissolved Solids (TDS) has increased dramatically at the downstream station since mining activities began. Conductivity, hardness, alkalinity, sulfates, sodium, calcium, and the metals iron, magnesium, and manganese have increased at the downstream (BM-006) station, but have remained fairly constant at the upstream (BM-005) station since 1995.

April flow data has fluctuated at both the upstream (BM-005) and the downstream (BM-006) stations between 1996 and 2000 (TABLE 1B). The pH has remained nearly neutral at both the upstream and downstream stations on Trough Fork. Total Suspended Solids (TSS) has remained constant since 1996 at both locations and Total Dissolved Solids (TDS) has increased substantially at the downstream station since mining activities began. Similar to the October data, conductivity, hardness, alkalinity, sulfates, sodium, calcium, and the metals iron, magnesium, and manganese have increased at the downstream (BM-006) station, but have remained fairly constant at the upstream (BM-005) station since 1996.

BENTHIC MACROINVERTEBRATE ANALYSIS

October Data

A slight increase in the number of individuals collected at the upstream (BM-005) station, and a sharper increase in the number of individuals collected at the downstream (BM-006) station has occurred since 1995 (TABLE 2A, FIGURE 2). Total abundances were lowest in 1995, however this may have resulted from a poor year, but no previous data are available to support this theory. Total number of taxa have remained very similar at both the upstream and the downstream stations. There does not appear to be changes in the total number of taxa collected at either station for the October sampling events (TABLE 2A, FIGURE 4). The number of EPT taxa, mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), from October data suggests no change in total number of EPT taxa at the upstream station, but a possible slight decline in total EPT taxa at the downstream station since October 1995 (TABLE 1A, FIGURE 6).

Benthic macroinvertebrate data was also analyzed to determine if mining related activities have effected three of the major functional feeding groups (scrapers, collector/filterers, and shredders). The relative abundances of both the scraper group and the collector/filterer group have been very sporadic in abundance during the October sampling events (TABLE 2A). No apparent trends between water quality or mining related activities and the abundance of these two functional feeding groups could be ascertained. However, the downstream station usually contained more scrapers than the upstream, and more collector/filterers were present at the downstream station than the upstream station when this functional feeding group was collected. No apparent trends could be determined for the shredder group but the downstream station usually contained a smaller relative abundance of shredders than the upstream station during the October sampling events (TABLE 2A). This likely resulted from the availability of detrital input rather than changes in water quality.

The Simpson's Diversity Index, the Shannon-Wiener Diversity Index, and the Shannon-Wiener Evenness indices have been calculated at the Trough Fork station since 1995. Both diversity indices indicated a difference between the upstream and downstream stations starting in October 1998. Prior to 1998, no differences in diversity measures occurred between the upstream and downstream stations during October. The Shannon-Wiener Evenness metric indicated similar results. A difference in the equitability of abundances of taxa between the two stations became apparent since 1998. The downstream (BM-006) station became noticeably less diverse, and abundances were less evenly distributed among the taxa, than the upstream (BM-005) station since October 1998 (TABLE 2A).

The most noticeable changes in these October macroinvertebrate data collected since 1995 has been a change in the sensitivity of the benthic community at the downstream station. The sensitivity at the upstream station has remained fairly unchanged since 1995, with similar percentages of the three sensitivity groups (sensitive, facultative, and tolerant) (TABLE 2A and

FIGURE 8). A trend towards a less sensitive, and more tolerant community is noticeable at the downstream station although some potential outliers occur in the data (FIGURE 9). Similarly, a steady increase in the Hilsenhoff Biotic Index (HBI) occurred at the downstream station for the October data which indicates an increase in tolerance(TABLE 2A and FIGURE 10).

April Data

A slight increase in the number of individuals collected at the upstream (BM-005) station, and a pronounced increase in the number of individuals collected at the downstream (BM-006) station has occurred since 1996 (TABLE 2B, FIGURE 3). Dramatic increases in the benthic macroinvertebrate community occurred in 1999, however this increase appears to be an anomaly. The total number of taxa collected have remained fairly constant at both the upstream and the downstream stations during the April sampling events (TABLE 2B, FIGURE 5). The number of EPT taxa, mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), indicated no change in total number of EPT taxa at the upstream station, and a slight decline in total EPT taxa at the downstream station since April 1996 (TABLE 1B and FIGURE 7).

Benthic macroinvertebrate data was analyzed to determine if mining related activities have effected the three major functional feeding groups (scrapers, collector/filterers, and shredders). The relative abundances of both the scraper group and the collector/filterer group have been very sporadic in abundance during the April sampling events (TABLE 2B). No apparent trends between water quality or mining related activities and the abundance of these two functional feeding groups could be ascertained. However, the downstream station usually contained more scrapers, and always contained more collector/filterers than the upstream station (TABLE 2B). Likewise, no apparent trends between water quality or mining related activities could be identified for the shredder group. However, the downstream station usually contained a smaller relative abundance of shredders than the upstream station during the April sampling events. As with thee October data, this likely resulted from the availability of detrital input rather than changes in water quality.

The Simpson's Diversity Index and the Shannon-Wiener Diversity Index both indicated a difference in diversity between the upstream and downstream stations in April 2000 (TABLE 2B). Previously, no differences in diversity measures occurred between the upstream and downstream stations during April. The Shannon-Wiener Evenness metric indicated similar results. A difference in the equitability of abundances of taxa between the two stations became apparent in 2000. The downstream (BM-006) station became noticeably less diverse, and abundances were less evenly distributed among the taxa, than the upstream (BM-005) station in April 2000 (TABLE 2A).

The most noticeable changes in these April macroinvertebrate data collected since 1996 has been a change in the sensitivity of the benthic community at the downstream station. The sensitivity at the upstream station has remained fairly unchanged since 1996, with similar percentages of the three sensitivity groups (sensitive, facultative, and tolerant) (TABLE 2B and

FIGURE 11). Although, a dramatic increase in the benthic macroinvertebrate community occurred in 1999, this increase appears to be an anomaly. A trend towards a less sensitive, and more tolerant community is noticeable at the downstream station (FIGURE 12). Similarly, a steady increase in the Hilsenhoff Biotic Index (HBI) occurred at the downstream station for the April data (TABLE 2B and FIGURE 13).

BENTHIC MACROINVERTEBRATE BIOMASS ANALYSIS

Total biomass at the upstream (BM-005) station on Trough Fork remained similar between years with a sharp drop in biomass during the October 1999 sampling event (FIGURE 14). However, total biomass at the downstream (BM-006) station on Trough Fork showed dramatic fluctuations between years, with no obvious trend. However, there may be somewhat of an increase in the biomass occurring at the downstream station since October, 1997.

Total biomass at the upstream (BM-005) station on Trough Fork was slightly more sporadic in the April data than in the October data, with no apparent trend (FIGURE 15). Similar to the October results, the April total biomass at the downstream (BM-006) station showed some dramatic fluctuations with a dramatic drop in biomass during April 1998, but a huge increase in biomass since the April 1999 sampling event.

Cumulative and average biomass per station for the five year sampling period indicated that biomass was slightly greater during the October (fall) sampling events for the upstream (BM-005) station, but that biomass was greater during the April (spring) sampling events for the downstream (BM-006) station (FIGURES 16 and 17). One very important aspect of the biomass evaluations is that cumulative and average biomass has been greater at the downstream station during both the April and October sampling events compared to the respective upstream sampling station (FIGURES 16 and 17). This is important because it indicates that with the increases in total abundances of aquatic insects occurring at the downstream station over time, biomass has remained greater at the downstream station, regardless of the change in species sensitivities or taxa.

HABITAT ANALYSIS

BM-005 (Upstream station on Trough Fork)

This station located on Trough Fork, downstream of the confluence with Tomblin Branch, has continued to receive marginal to optimal scores for substrate and instream cover (primary) ratings, marginal to optimal channel morphology (secondary) ratings, and poor to sub-optimal riparian and bank structure (tertiary) ratings. This station has recently received a marginal score for "embeddedness" due to increases in sedimentation. Small substrate sizes such as sand and silt can decrease interstitial spaces and reduce aquatic habitat. The increases in sedimentation have been due to road widening in the immediate area, and are not related to mining activities since this station is upstream from any mining or logging activities. Therefore, a marginal score for "channel alteration" has been recently given to this station. Stream banks have been moderately stable, and have had poor (< 50% of the stream bank surface covered in vegetation) vegetative cover. The "riparian zone width" has been poor on both banks because human disturbance (road and a private residence) is within 6 meters. This station has had a variety of flows during the sampling events, and provides marginal aquatic habitat.

BM-006 (Downstream station on Trough Fork)

This station located on Trough Fork, downstream from the confluence with Sugarcamp Branch, has received marginal to optimal scores for substrate and instream cover (primary) ratings, marginal to optimal channel morphology (secondary) ratings, and poor to optimal riparian and bank structure (tertiary) ratings. This station has recently received a marginal score for "embeddedness" due to increases in sand and silt substrates. Small-sized substrates can decrease interstitial spaces and reduce aquatic habitat. Stream banks have been stable, and 70 - 90% of the left stream bank was covered by native vegetation. However, vegetative cover has been poor on the right stream bank and covered 50% or less of the bank. The "riparian zone width" has been optimal on the left bank because human disturbance is greater than 18 meters. The "riparian zone width" has been poor on the right bank because human disturbance (roads) is within less than 6 meters. This station has had excellent flow at the time of sampling, and provides sub-optimal aquatic habitat.

DISCUSSION

Benthic macroinvertebrate data has been collected at two stations on Trough Fork for the past five years. The primary purpose of this report was to detect any trends in the water chemistry, benthic macroinvertebrate, and habitat data collected over the five year period. Pre-mining data were collected in October 1995 and April 1996 to represent the Trough Fork watershed prior to mining-related influences. These pre-mining data, and post mining data since 1996 were examined to identify trends that may have occurred as a result of mining influences. Annual and seasonal variations in benthic macroinvertebrate and physical parameters (temperature, flow, water chemistry, and available habitat) are common. Therefore these data were analyzed on the basis of long-term trends rather than year-to-year, or seasonal, comparisons.

Stream flow has varied at both Trough Fork stations during both April and October sampling events for the past 5 years (TABLES 1A and 1B). Flow variations are common, and naturally increase as a result of precipitation events, or can become very low during drought or dry periods of the year. There does not appear to be any change in flow as a result from mining activity in the Trough Fork watershed. Change in flow as a result of mining activities may have been detectable if daily records of flow were recorded. The semi-annual measurements of flow from this report would not likely identify true changes in the Trough Fork flow regime. However, Total Dissolved Solids (TDS), conductivity, hardness, alkalinity, sulfates, sodium, calcium, iron, magnesium, and manganese have all increased at the downstream site during the past 5 years. The increases in these water quality constituents likely resulted from mining related activities which can include road construction and maintenance, vegetation clearing, and vehicle traffic. Although increases in these water quality constituents have occurred at the downstream station, no single parameter should severely inhibit the macroinvertebrate community in the downstream portion of Trough Fork. Changes in the benthic macroinvertebrate community is likely resulting from a combination of several parameters near limiting levels which may have initiated changes in the tolerances of the benthic macroinvertebrate community. Parameters such as Total Suspended Solids (TSS) and pH have remained relatively consistent following mining activities.

A slight increase in the number of individuals collected at the upstream Trough Fork station and a more obvious increase at the downstream station has occurred in the past 5 years (TABLES 2A and 2B). However, no changes in the total number of taxa collected has occurred at the upstream or downstream stations since 1995. The abundances of functional feeding groups such as the scrapers, collector/filterers, and shredders has varied between years, and no trends could be identified. The diversity and evenness metrics have all indicated a decline in the diversity and equatability of abundances at the downstream station in the past two years. Typically, when large increases in abundance occurs, the number of taxa also should increase which results in higher species diversity indices. However, despite the large increases in abundance at the downstream Trough Fork station, the diversity indices have declined due to the increases in abundance from only a couple of tolerant taxa. Evenness represents the equatability among taxa, and a community with taxa consisting of fairly equal abundances is healthier than a community dominated by a few very abundant taxa.

The most obvious change in the benthic macroinvertebrate community at the downstream station has been a decline in the number of sensitive individuals and an increase in the number of tolerant individuals. This is demonstrated by the increase in the Hilsenhoff Biotic Index (HBI), and changes in the three sensitivity groups (sensitive, facultative, and tolerant) (TABLES 2A and 2B). During both sampling seasons, the upstream community has remained fairly well balanced with relatively equal percentages of organisms from the three sensitivity groups. However, the downstream station has continually shifted from a fairly well balanced community to a community dominated by tolerant individuals. The shift to a community dominated by tolerant individuals may be related to the continued increase in some water chemical constituents at the downstream station. The declines in diversity and evenness metrics at the downstream Trough Fork station are also likely related to mining activities. This more tolerant community now consists largely of the midges, Chironomidae, and the aquatic worms, Oligochaeta. These two taxa are very prolific, producing many cohorts per year, and can become very predominant in some areas. These large increases in abundance of these two taxa have caused the diversity and evenness metrics to decline.

Cumulative and average benthic macroinvertebrate biomass data indicates that biomass has been greater in the fall (October) at the upstream station, and greater in the spring (April) at the downstream station (FIGURES 16 and 17). Cumulative biomass and average biomass per station indicate that biomass is also greater at the downstream station than at the upstream station. This larger biomass at the downstream station is solely the function of the much greater abundances collected at the downstream station. Resource agencies have expressed the concern and need to determine if mining activity results in a decrease in the benthic macroinvertebrate biomass. Although there may be an increase in October biomass occurring at the downstream station since mining activities began in 1996, this increase has not been identified for the April data since downstream April biomass has been more sporadic than downstream October data. There may be an increase in biomass occurring at the downstream station, but it will take a few more sampling events to positively evaluate this claim. It is interesting to note that biomass has remained fairly consistent at the upstream station throughout the life of this study, with relatively dramatic increases appearing at the downstream station after April 1998.

No dramatic change in the physical habitat at either station has occurred, with the exception of an increase in the amount of sand and silt to the substrate. Some of this change in the substrate composition is likely due to mining related activities such as road maintenance, but some may also be from natural increases resulting from erosion during heavy precipitation events. An increase in sedimentation is usually followed by the dramatic reduction of the scraper group of aquatic insects. Sedimentation can reduce the amount of interstitial spaces between pebbles and gravel and reduce the amount of available habitat. Scrapers also require smooth surfaces to feed on the periphyton which attaches to larger substrate particles, usually gravel size and larger. Heavy sand and silt deposits can abrade the algae from the substrate or cover the surface of the substrate and prevent algal growth. Scrapers abundances have been similar over the past five years, and therefore sedimentation has not likely inhibited periphyton growth.

CONCLUSION

Two long-term monitoring stations on Trough Fork have been sampled semi-annually for five years. Water chemistry, benthic macroinvertebrate, and habitat information has been collected. The initial sampling periods were conducted prior to mining related disturbances, and therefore represent the pre-mining conditions. The upstream station is located above the mining area and upstream of most human influences. The downstream station encompasses active mining areas and is influenced by sediment control structures/treatment ponds, and haul road traffic.

Water quality at both stations on Trough Fork indicated fluctuations in flow, and undetectable levels of most metals. Although several chemical parameters have increased over time at the downstream station, no single physical or chemical water quality parameter appears to be limiting to the benthic community at the downstream station. However, the combination of several parameters at near limiting levels may be responsible for changes in the benthic macroinvertebrate community.

The benthic macroinvertebrate community has shifted from a sensitive, well balanced benthic community with relatively equal numbers of sensitive, facultative, and tolerant individuals, to a community dominated by tolerant and facultative individuals. This shift has resulted in diversity and evenness metrics that indicated a less diverse and less evenly distributed community at the downstream station. Nevertheless, total taxa collected at the downstream station has remained unchanged, and total abundances have actually increased substantially. These increases in total abundance resulted from more tolerant individuals.

Biomass of the benthic macroinvertebrate samples revealed that biomass was usually greater at the downstream station than at the upstream station for most sampling events. Cumulative and average biomass for the past five years is considerably greater at the downstream station compared to the upstream station. Cumulative biomass for the upstream station is greater in the fall than in the spring; cumulative biomass for the downstream station is greater in the spring than in the fall.

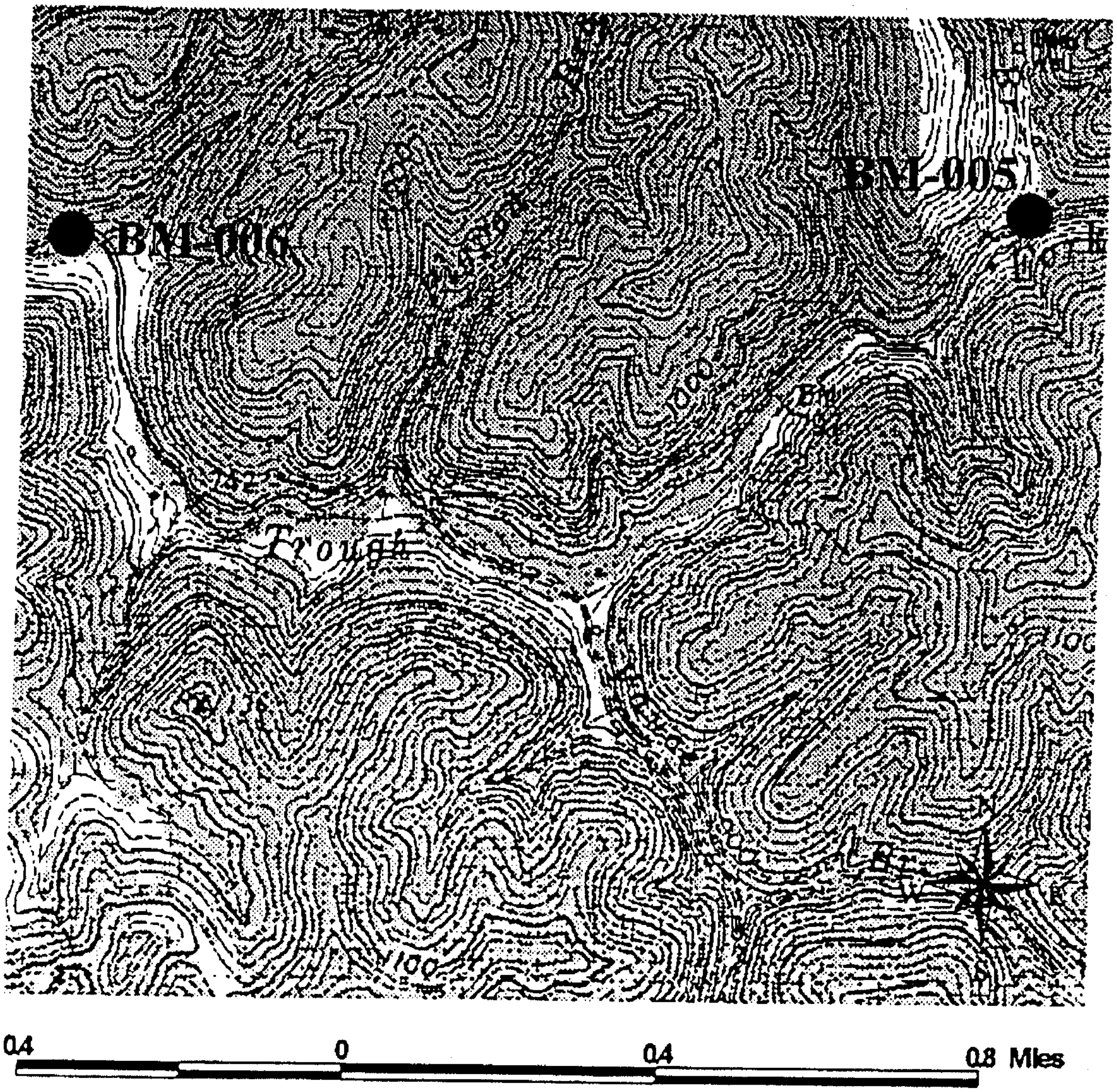

FIGURE 1. Approximate location of macroinvertebrate and fisheries sampling stations on Trough Fork. Pen Coal Corporation, April 2000.

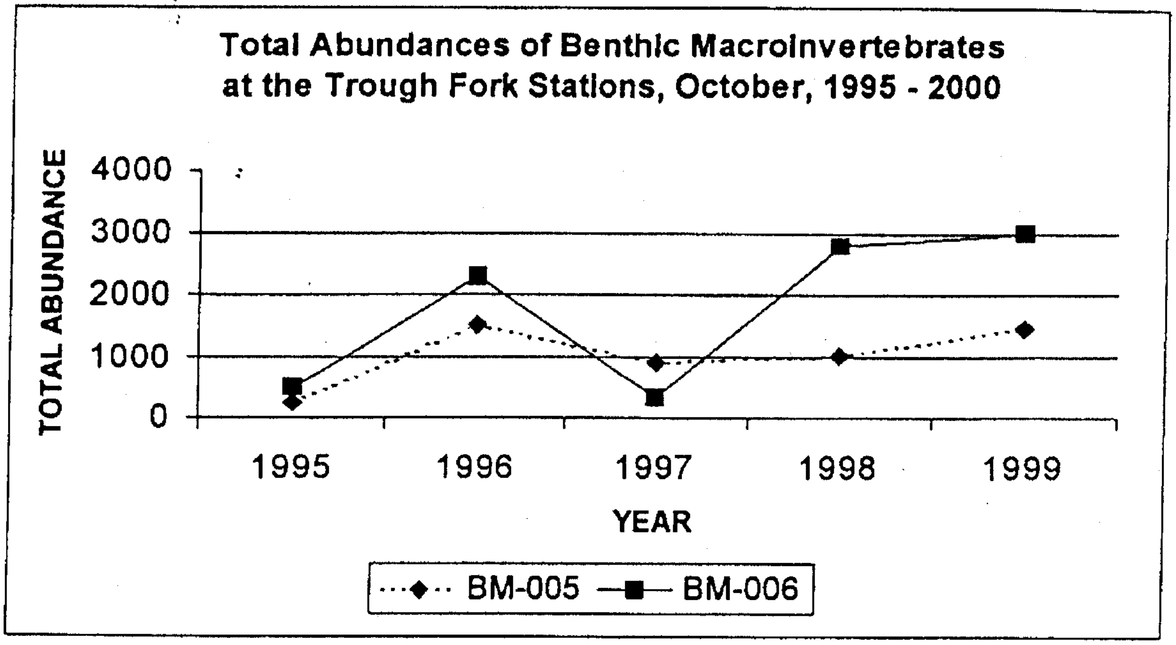

FIGURE 2. Total abundances of benthic macroinvertebrates collected in October at the upstream (BM-005) and the downstream (BM-006) Trough Fork stations. Pen Coal Corporation, May 2000.

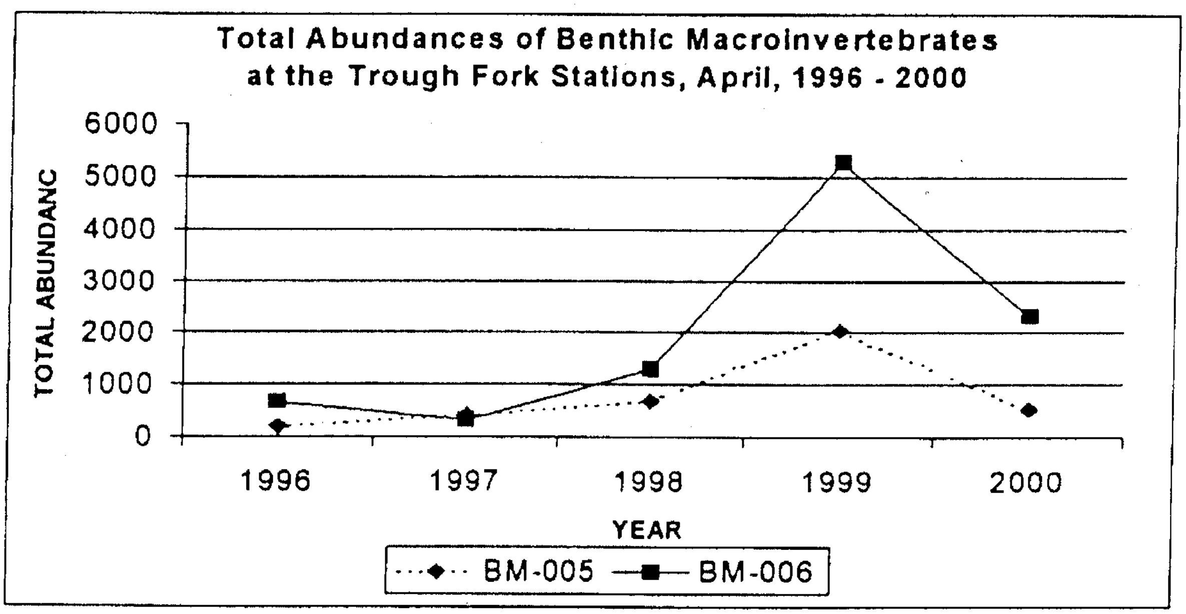

FIGURE 3. Total abundances of benthic macroinvertebrates collected in April at the upstream (BM-005) and the downstream (BM-006) Trough Fork stations. Pen Coal Corporation, May 2000.

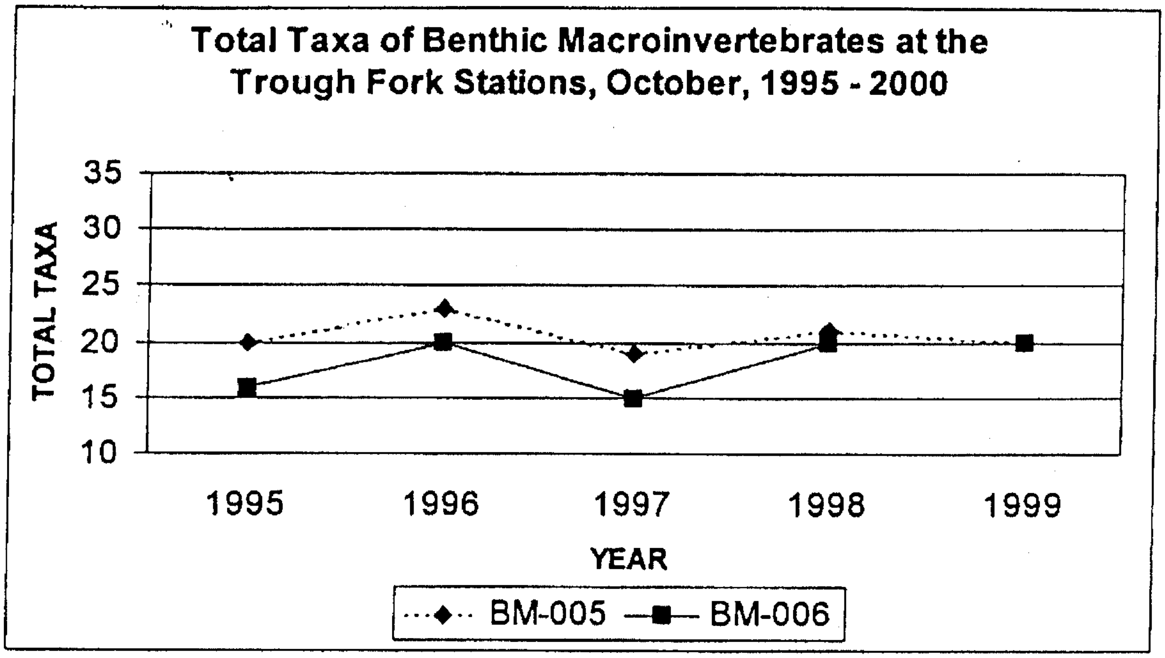

FIGURE 4. Total number of taxa of benthic macroinvertebrates collected in October at the upstream (BM-005) and the downstream (BM-006) Trough Fork stations. Pen Coal Corporation, May 2000.

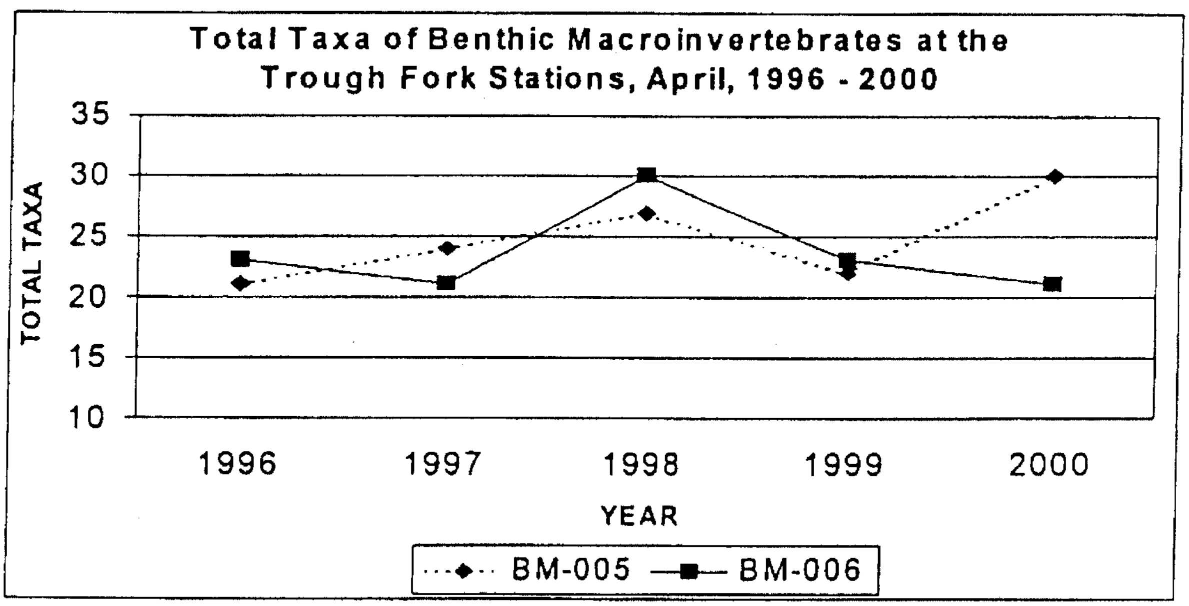

FIGURE 5. Total number of taxa of benthic macroinvertebrates collected in April at the upstream (BM-005) and downstream (BM-006) Trough Fork stations. Pen Coal Corporation, May 2000.

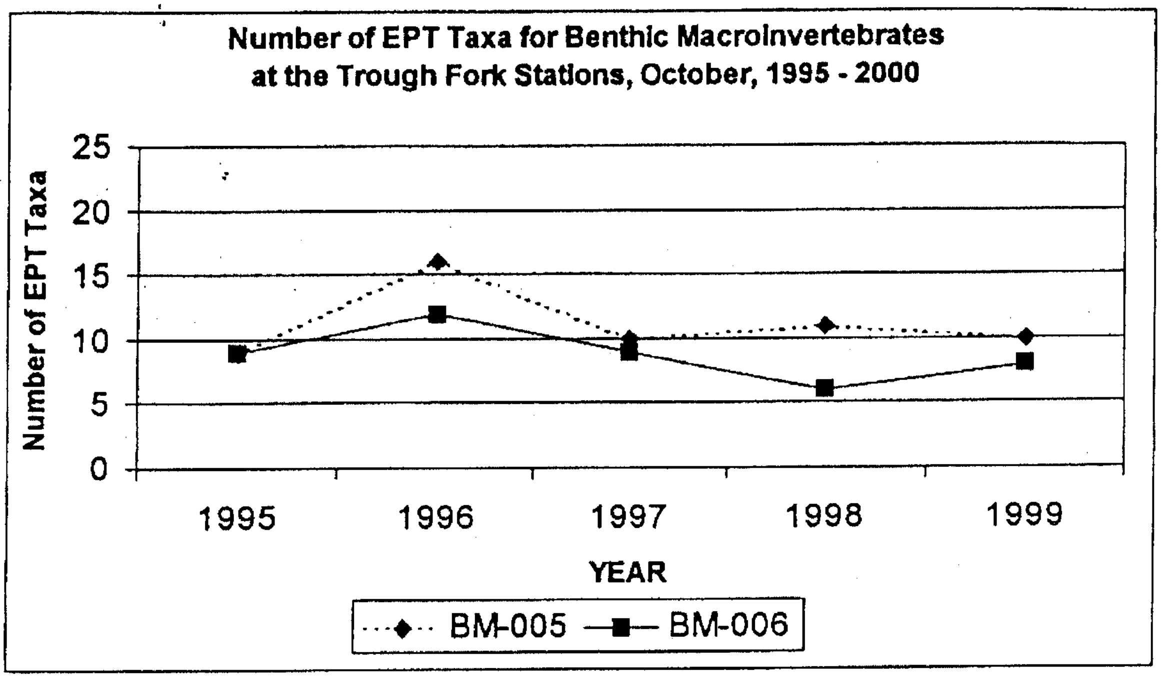

FIGURE 6. Number of EPT taxa of benthic macroinvertebrates collected in October at the upstream (BM-005) and the downstream (BM-006) Trough Fork stations. Pen Coal Corporation, May 2000.

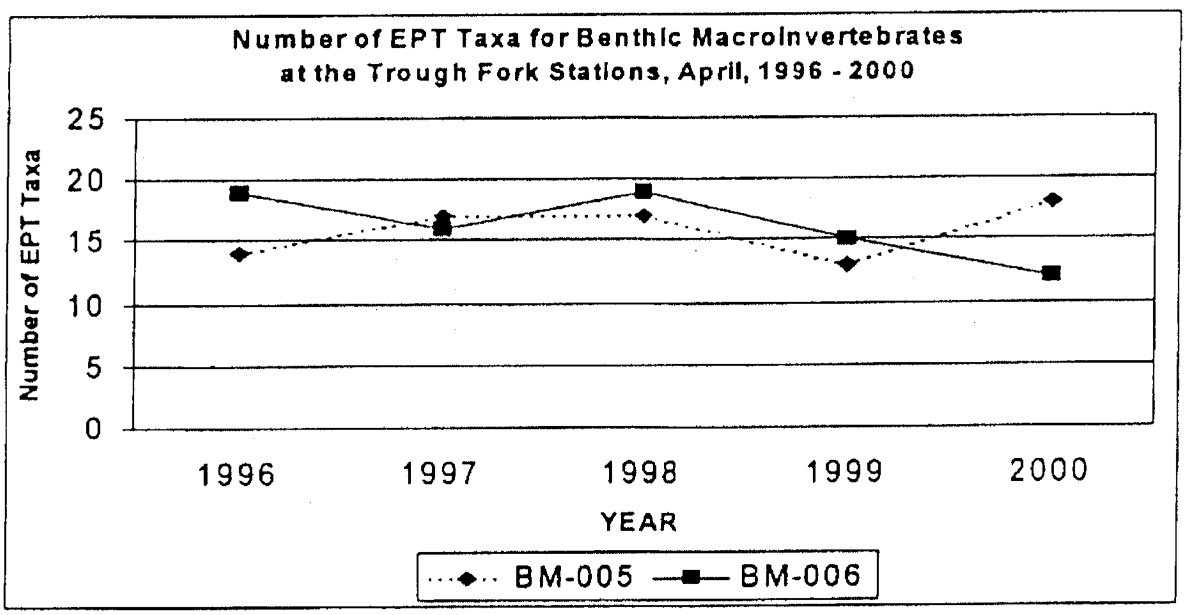

FIGURE 7. Number of EPT taxa of benthic macroinvertebrates collected in April at the upstream (BM-005) and the downstream (BM-006) Trough Fork stations. Pen Coal Corporation, May 2000.

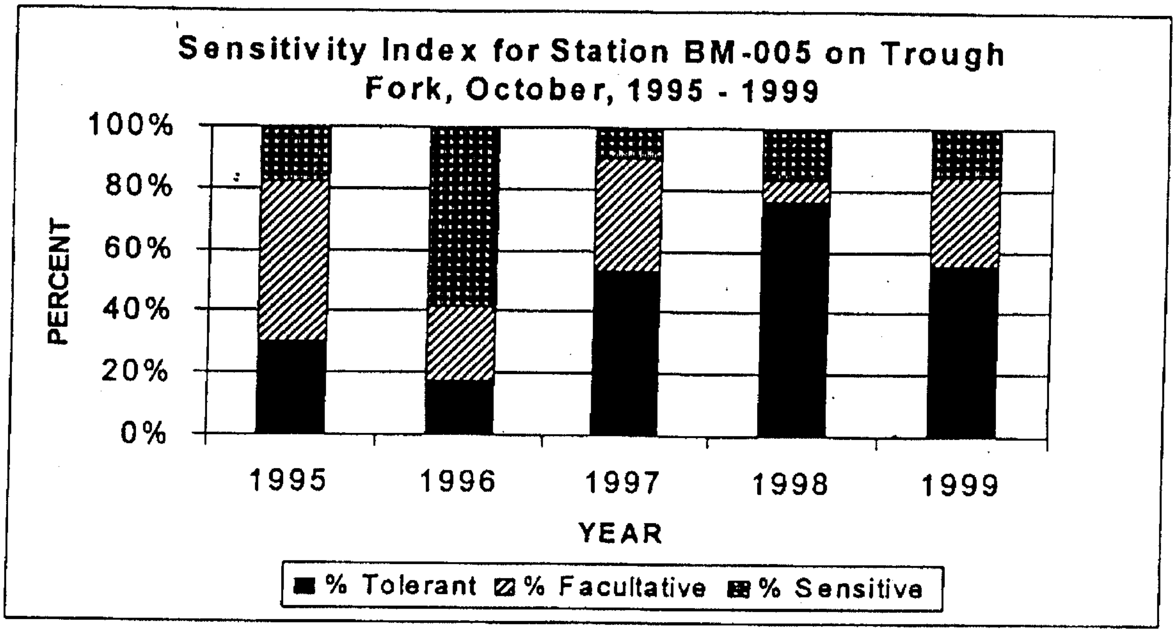

FIGURE 8. Sensitivity of the October benthic macroinvertebrate community at the upstream station on Trough Fork. Pen Coal Corporation, May 2000.

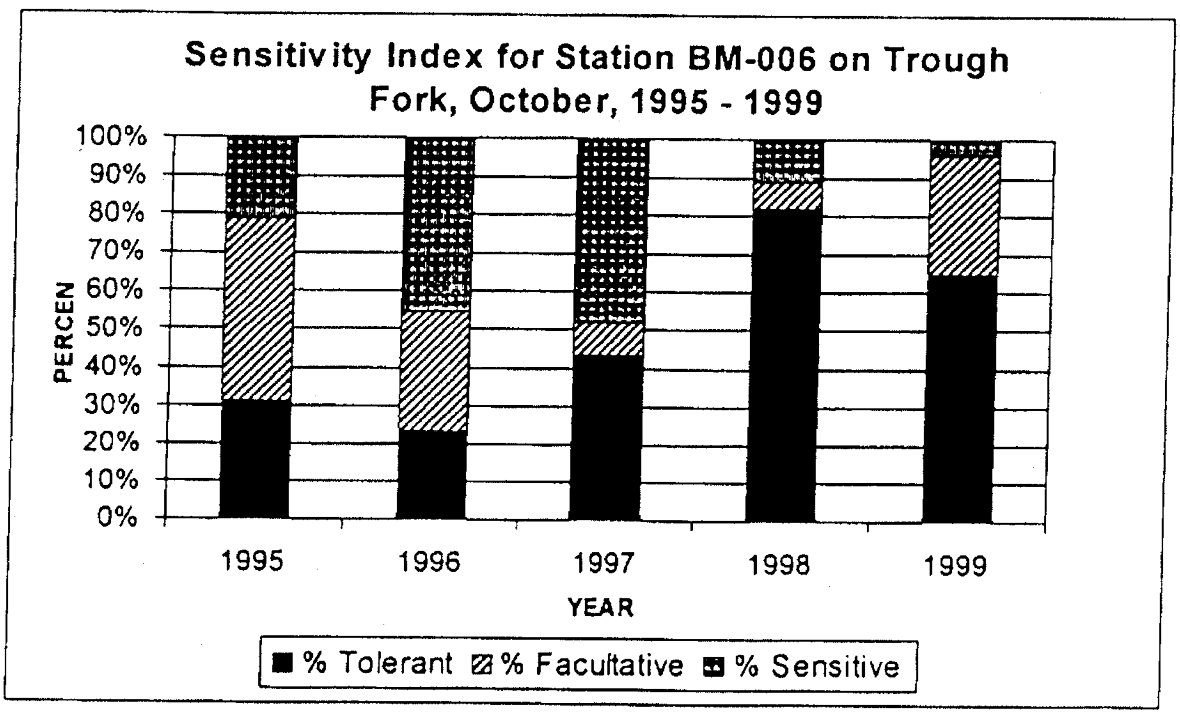

FIGURE 9. Sensitivity of the October benthic macroinvertebrate community at the downstream station on Trough Fork. Pen Coal Corporation, May 2000.

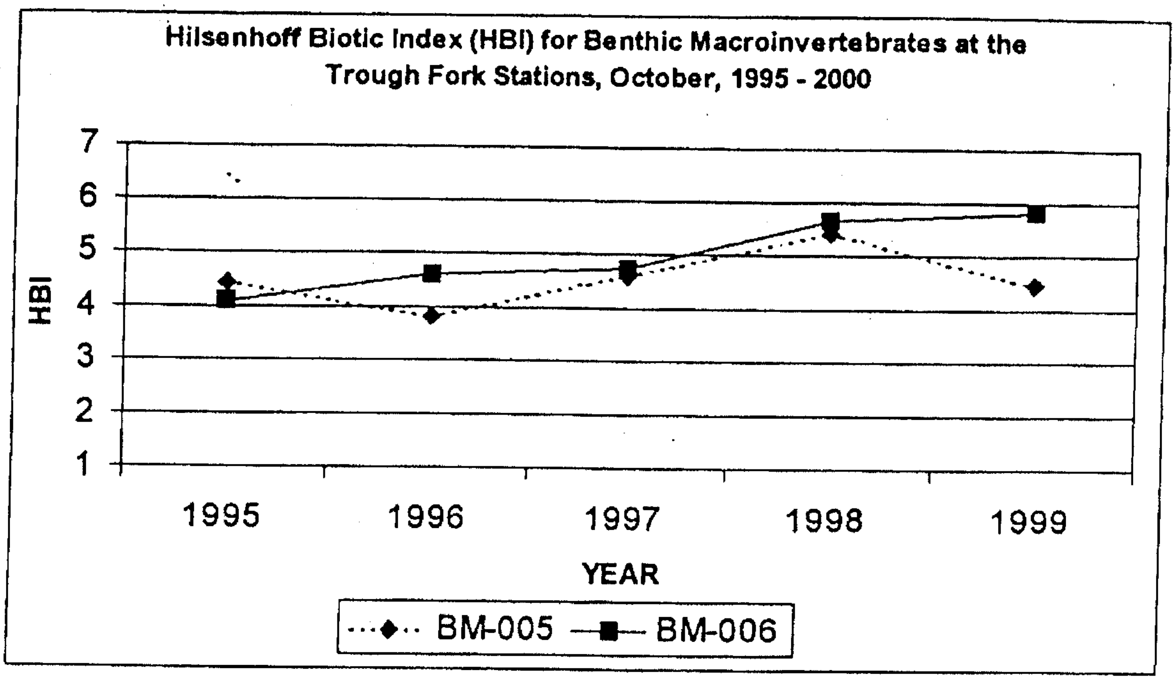

FIGURE 10. Hilsenhoff Biotic Index (HBI) of the October benthic macroinvertebrate communities at the upstream (BM-005) and downstream (BM-006) stations on Trough Fork. Pen Coal Corporation, May 2000.

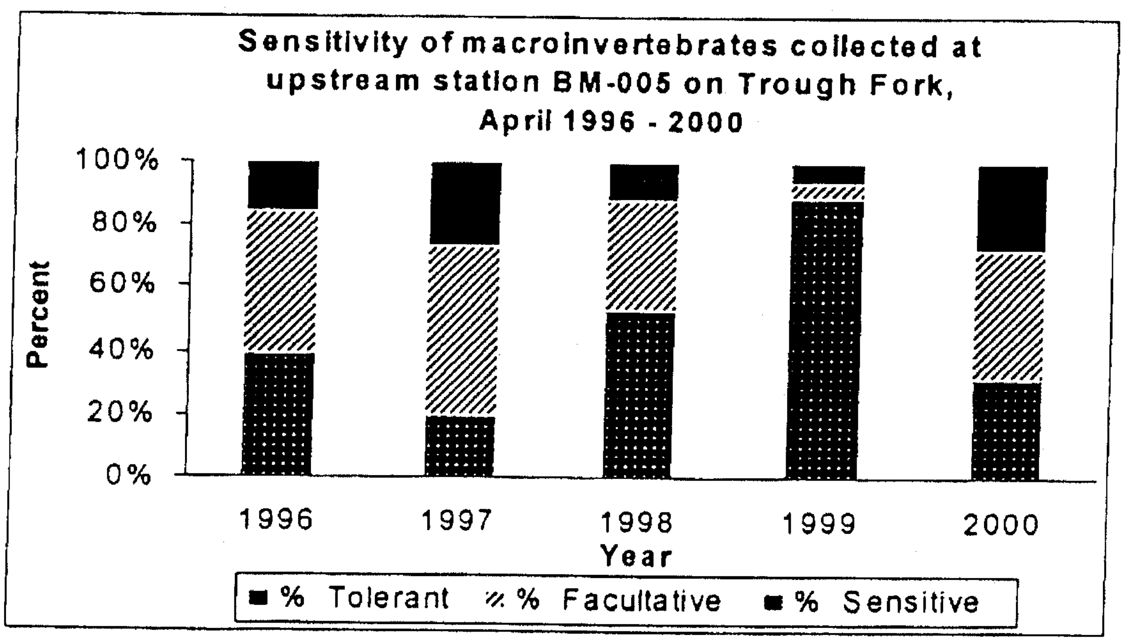

FIGURE 11. Sensitivity of the April benthic macroinvertebrate community at the upstream station on Trough Fork. Pen Coal Corporation, May 2000.

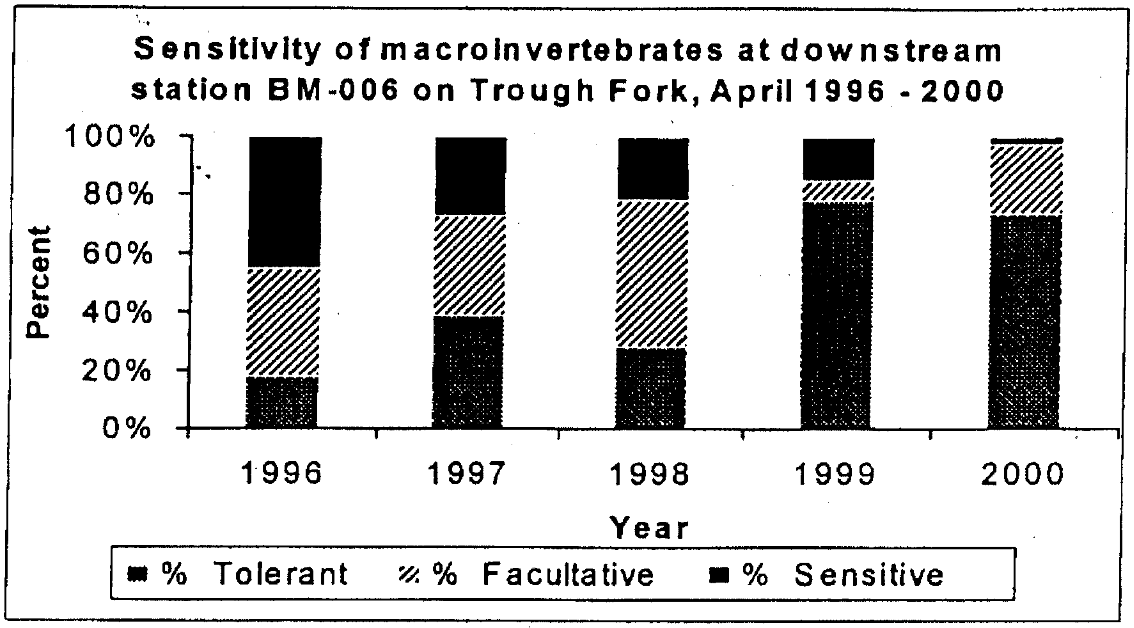

FIGURE 12. Sensitivity of the April benthic macroinvertebrate community at the downstream station on Trough Fork. Pen Coal Corporation, May 2000.

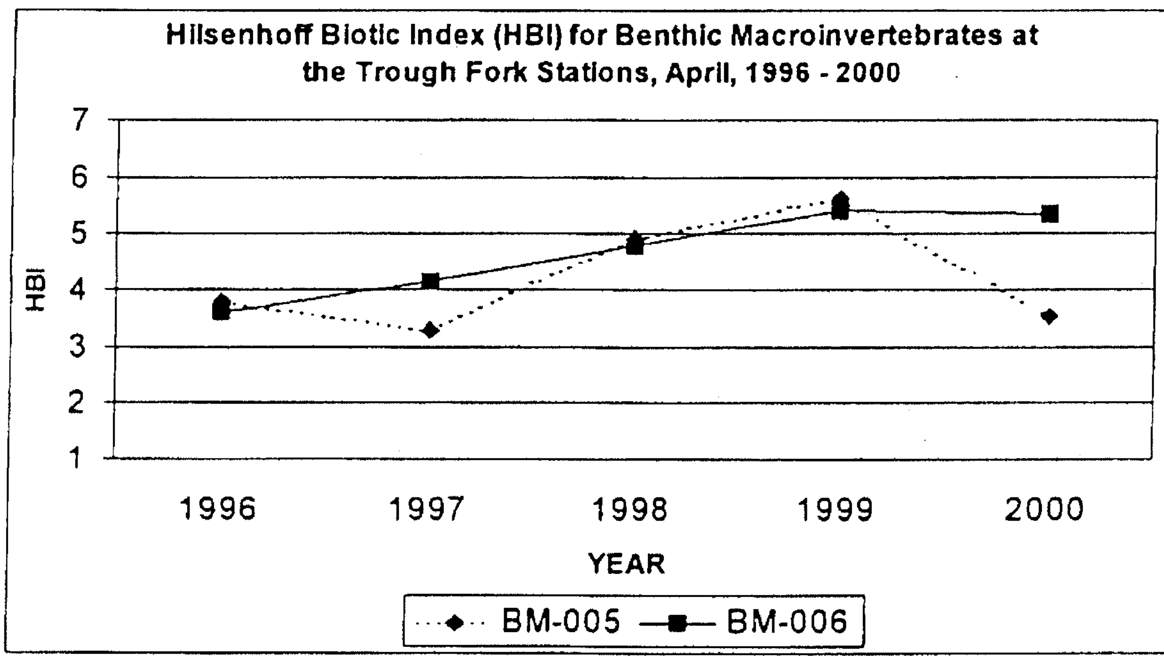

FIGURE 13. Hilsenhoff Biotic Index (HBI) of the April benthic macroinvertebrate communities at the upstream (BM-005) and downstream (BM-006) stations on Trough Fork. Pen Coal Corporation, May 2000.

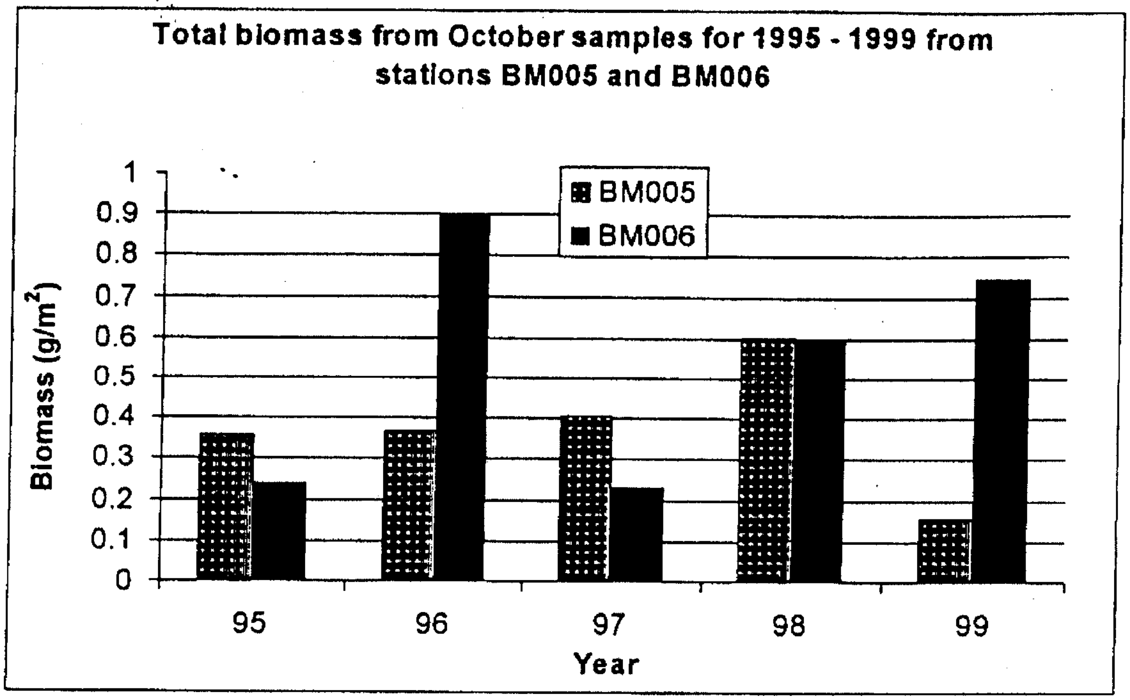

FIGURE 14. Total macroinvertebrate biomass from the October samples from the upstream (BM-005) and the downstream (BM-006) stations on Trough Fork. Pen Coal Corporation, May 2000.

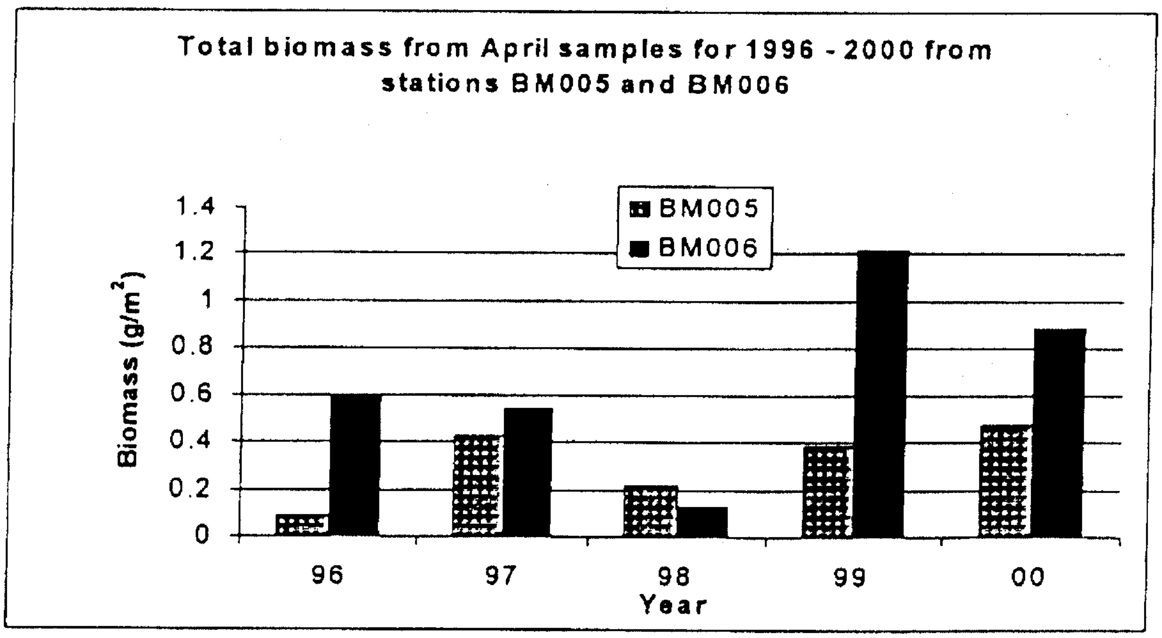

FIGURE 15. Total macroinvertebrate biomass from the April samples from the upstream (BM-005) and the downstream (BM-006) stations on Trough Fork. Pen Coal Corporation, May 2000.

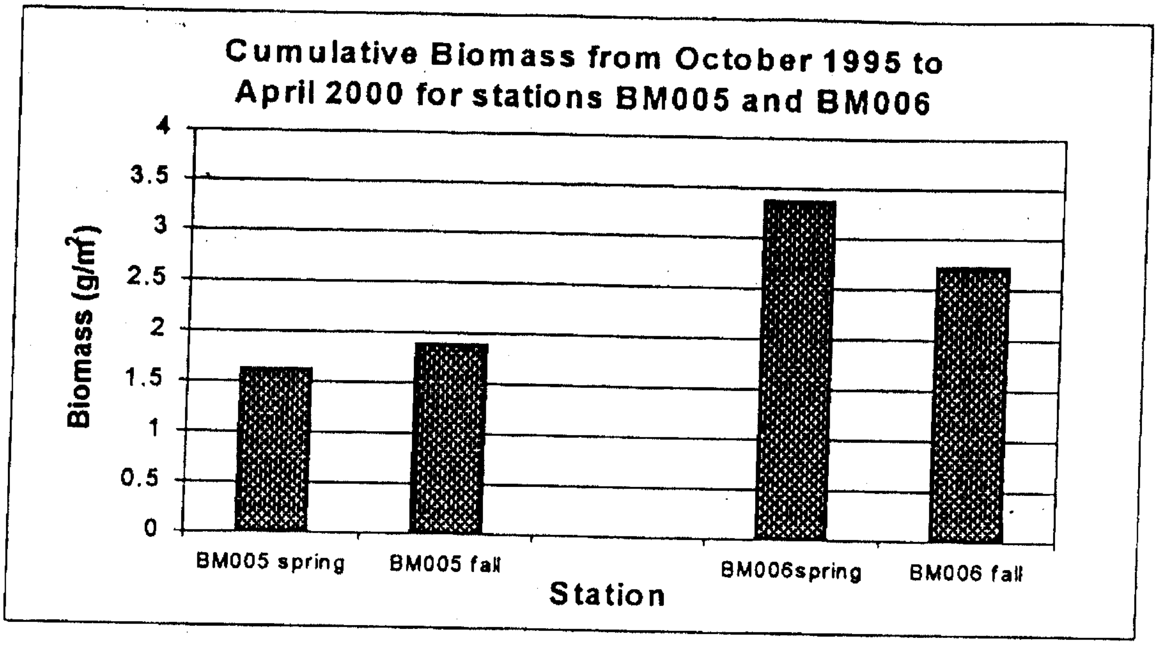

FIGURE 16. Cumulative macroinvertebrate biomass from the combined 5 years of samples from the upstream (BM-005) and the downstream (BM-006) stations on Trough Fork. Pen Coal Corporation, May 2000.

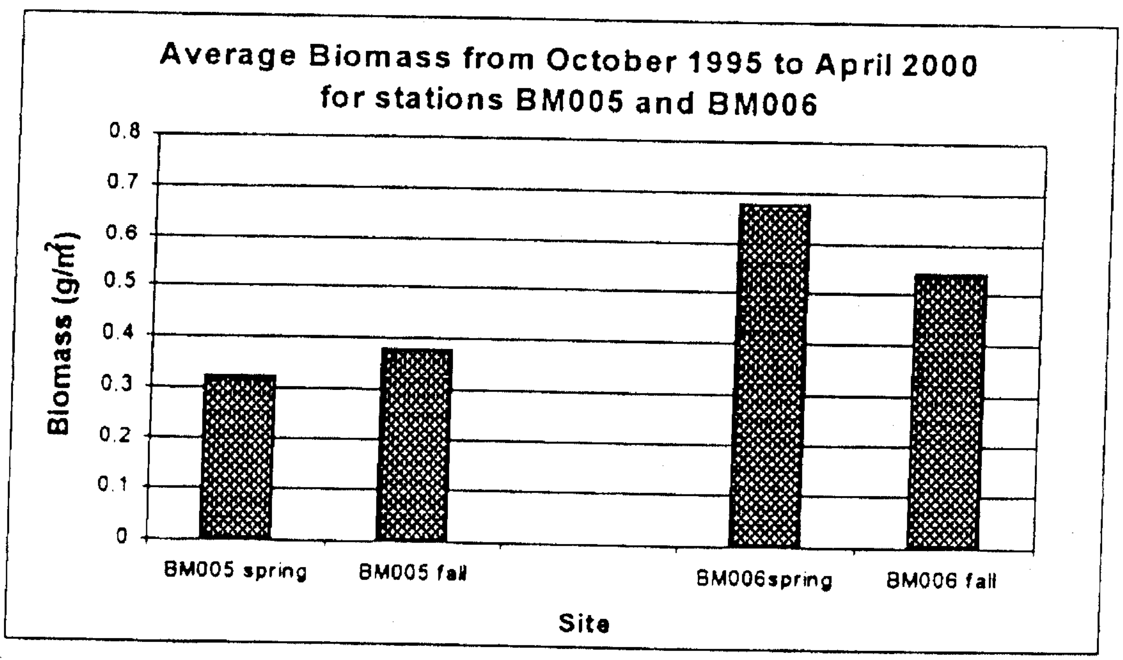

FIGURE 17. Average biomass per macroinvertebrate sample from the combined 5 years of samples from the upstream (BM-005) and the downstream (BM-006) stations on Trough Fork. Pen Coal Corporation, May 2000.

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Table 1A. Selected water quality parameters of Stations BM-005 (Upstream) and BM-006 (Downstream) on Trough Fork; October data 1995 - 1999. Pen Coal Corporation.*

	OCT 1995		OCT 1996		OCT 1997		OCT 1998		OCT 1999	
	BM-005	BM-006	BM-005	BM-006	BM-005	BM-006	BM-005	BM-006	BM-005	BM-006
Flow (ft^3/sec)	0.2	0.2	3.2	4.7	0.02	0.14	0.05	0.31	0.028	0.180
pH (SU)	6.53	6.08	7.21	7.12	7.55	7.60	6.69	7.47	6.83	7.16
Conductivity (μmhos)	93	176	65	242	124	469	105	1061	69	489
Total Dissolved Solids (mg/l)	60	107	32	122	79	577	61	727	99	424
Total Suspended Solids (mg/l)	5	2	<1.0	1.0	1	4	<1.0	2	2	1
Hardness (mg/l)	35.8	67.3	24.2	116.1	43	349	48	254	44.2	322
Alkalinity (mg/l)	21.8	24.0	11.3	36.9	33.1	106.0	37	137	39.6	105
Acidity (mg/l)	<1.0	<1.0	<1.0	<1.0	11.5	15.5	<1.0	<1.0	<1.0	<1.0
Sulfates (mg/l)	12.1	41.4	12.8	60.1	20.3	282.0	14.5	354	16.4	305
Total Sodium (mg/l)	1.86	4.90	1.35	2.59	2.96	12.0	2.70	141	2.29	27.0
Total Aluminum (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.051	0.038	0.086	0.103
Total Calcium (mg/l)	7.82	14.2	5.62	30.6	9.84	86.3	11.3	51.9	10.9	80.6
Total Iron (mg/l)	0.32	0.10	<0.10	<0.10	0.140	0.106	0.183	0.186	0.102	0.317
Total Magnesium (mg/l)	3.96	7.74	2.48	9.63	4.46	32.5	4.81	30.3	4.14	29.2
Total Manganese (mg/l)	<0.05	<0.05	<0.05	0.15	0.034	0.049	0.032	0.121	0.009	0.235
Chlorides (mg/l)	—	—	—	—	2.1	2.9	3.9	4.6	1.6	1.8

* Parameters not exceeding minimum detection limits have been omitted from this table.

Table 1B. Selected water quality parameters of Stations BM-005 (Upstream) and BM-006 (Downstream) on Trough Fork; April data 1996 - 2000. Pen Coal Corporation.*

	APRIL 1996		APRIL 1997		APRIL 1998		APRIL 1999		APRIL 2000	
	BM-005	BM-006	BM-005	BM-006	BM-005	BM-006	BM-005	BM-006	BM-005	BM-006
Flow (ft^3/sec)	1.6	4.8	1.3	5.0	3.75	8.66	1.24	1.80	2.83	1.83
pH (SU)	7.75	7.69	7.29	7.35	6.92	6.54	6.88	7.41	6.77	7.50
Conductivity (μmhos)	58	64	67	221	53.6	611	59	470	90.2	530
Total Dissolved Solids (mg/l)	54	64	49	129	31	407	43	281	33	103
Total Suspended Solids (mg/l)	<1.0	15	5	5	<1.0	9	<1	<1	3	5
Hardness (mg/l)	19.9	22.4	25.8	99.2	20.4	303	27.4	154	20.7	66.9
Alkalinity (mg/l)	22.6	20.9	9.0	27.9	11.7	66.4	9.7	36.9	10.4	22.0
Acidity (mg/l)	19.8	19.3	<1.0	<1.0	<1.0	<1.0	<1	<1	5.9	<1.0
Sulfates (mg/l)	13.6	15.3	15.8	55.7	14.6	214	19.0	208	15.2	49.1
Total Sodium (mg/l)	1.08	1.05	1.27	2.36	1.06	3.48	1.81	48.2	1.30	2.46
Total Aluminum (mg/l)	0.19	0.60	0.052	0.064	0.224	0.127	0.045	<0.030	0.240	0.224
Total Calcium (mg/l)	4.09	4.44	5.52	25.2	4.36	80.2	6.46	31.3	4.74	16.6
Total Iron (mg/l)	0.19	0.72	0.089	0.107	0.240	1.03	0.118	0.219	0.335	0.350
Total Magnesium (mg/l)	2.35	2.74	2.92	8.82	2.32	24.9	2.73	18.4	2.16	6.19
Total Manganese (mg/l)	<0.05	0.06	0.005	0.236	<0.05	2.33	0.004	0.080	0.010	0.165
Chlorides (mg/l)	—	—	1.6	1.8	<1.0	1.3	1.4	2.4	1.5	2.5

* Parameters not exceeding minimum detection limits have been omitted from this table.

Table 2A. Selected benthic macroinvertebrate metrics of Stations BM-005 (Upstream) and BM-006 (Downstream) on Trough Fork; October data 1995 - 1999. Pen Coal Corporation.

	OCT 1995		OCT 1996		OCT 1997		OCT 1998		OCT 1999	
	BM-005	BM-006	BM-005	BM-006	BM-005	BM-006	BM-005	BM-006	BM-005	BM-006
Total Individuals Collected	220	496	1519	2277	907	308	1009	2777	1462	2984
Taxa Richness	20	16	23	20	19	15	21	20	20	20
% Sensitive Abundance (Taxa)	18% (6)	29% (7)	58% (7)	45% (8)	10% (6)	48% (5)	17% (7)	11% (5)	16% (6)	4% (6)
% Facultative Abundance (Taxa)	51% (5)	43% (5)	24% (12)	31% (7)	37% (7)	8% (6)	7% (8)	7% (6)	29% (9)	31% (7)
% Tolerant Abundance (Taxa)	30% (4)	28% (4)	17% (4)	23% (4)	53% (6)	43% (4)	76% (6)	83% (9)	56% (5)	65% (7)
Scrapers : Collector/Filterers	18:0	113:0	764:88	647:171	61:0	129:0	58:4	250:88	40:8	68:16
% Shredders	3%	0%	7%	0%	5.0%	1.6%	0.3%	0.0%	2.9%	3.1%
# of EPT Taxa	9	9	16	12	10	9	11	6	10	8
Hilsenhoff Biotic Index (HBI)	4.44	4.08	3.80	4.59	4.58	4.73	5.40	5.65	4.47	5.83
Simpson's Diversity Index	0.84	0.86	0.90	0.90	0.79	0.76	0.69	0.47	0.82	0.62
Shannon-Wiener Diversity Index	3.21	3.06	3.81	3.60	2.90	2.66	2.43	1.64	3.01	2.02
Shannon-Weiner Evenness	0.79	0.76	0.84	0.83	0.68	0.68	0.55	0.38	0.70	0.47

Table 2B. Selected benthic macroinvertebrate metrics of Stations BM-005 (Upstream) and BM-006 (Downstream) on Trough Fork; April data 1996 - 2000. Pen Coal Corporation.

	APRIL 1996		APRIL 1997		APRIL 1998		APRIL 1999		APRIL 2000	
	BM-005	BM-006	BM-005	BM-006	BM-005	BM-006	BM-005	BM-006	BM-005	BM-006
Total Individuals Collected	193	651	398	328	676	1303	2050	5292	543	2325
Taxa Richness	21	26	24	26	27	30	22	23	30	21
% Sensitive Abundance (Taxa)	16% (6)	45% (13)	27% (5)	27% (6)	12% (7)	22% (6)	6.5% (7)	15.2% (9)	27.8% (8)	2.9% (4)
% Facultative Abundance (Taxa)	45% (11)	37% (9)	53% (13)	34% (13)	35% (12)	50% (17)	4.7% (9)	6.5% (9)	40.9% (15)	23.7% (11)
% Tolerant Abundance (Taxa)	39% (4)	18% (4)	20% (6)	39% (7)	53% (7)	28% (7)	88.4% (6)	78.3% (5)	31.3% (7)	73.5% (5)
Scrapers : Collector/Filterers	12:6	211:76	95:15	77:18	68:5	279:58	94:2	784:216	96:13	47:118
% Shredders	6%	10%	18%	11%	11.8%	14.2%	2.5%	1.4%	30.0%	6.1%
# of EPT Taxa	14	19	17	16	17	19	13	15	18	12
Hilsenhoff Biotic Index (HBI)	3.77	3.57	3.28	4.14	4.91	4.79	5.64	5.42	3.53	5.35
Simpson's Diversity Index	0.81	0.87	0.88	0.82	0.76	0.86	0.36	0.49	0.91	0.57
Shannon-Weiner Diversity Index	3.17	3.48	3.39	3.27	3.08	3.13	1.42	1.53	4.07	2.03
Shannon-Weiner Evenness	0.72	0.74	0.74	0.71	0.65	0.64	0.32	0.34	0.83	0.46

Weakland, Cathy, A., and Wood, Petra Bohall. "Cerulean Warbler (Dendroica Cerulea) Microhabitat and Landscape-level Habitat Characteristics in Southern West Virginia in Relation to Mountaintop Mining/Valley Fills". Final Project Report. USGS Biological Resources Division and West Virginia University, Division of Forestry. December 2002.

CERULEAN WARBLER (*DENDROICA CERULEA*) MICROHABITAT AND LANDSCAPE-LEVEL HABITAT CHARACTERISTICS IN SOUTHERN WEST VIRGINIA IN RELATION TO MOUNTAINTOP MINING/VALLEY FILLS

Final Project Report

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ABSTRACT

The Cerulean Warbler (*Dendroica cerulea*) is a species of conservation concern in eastern North America, where declines in its population have been documented over the last several decades. Both habitat fragmentation and increased edge may negatively impact Cerulean Warbler populations. A high proportion of this species' population occurs in forested areas of southern West Virginia, where it may be threatened by loss and degradation of forested habitat from mountaintop mining/valley fills (MTMVF). We examined the impact of forest fragmentation (in particular the effects of fragment size and response to edges) on Cerulean Warbler densities from a landscape perspective using territory mapping techniques and geographic information system (GIS) technology. Specific objectives were: (1) to quantify Cerulean Warbler territory density and indices of reproductive success in forests fragmented by MTMVF mining and in relatively intact blocks of forest, (2) to quantify landscape characteristics affecting Cerulean Warbler territory density, and (3) to quantify territory-level characteristics of Cerulean Warbler habitat. The study area included portions of 4 counties in southwestern West Virginia. Territory density was determined using spot-mapping procedures, and reproductive success was estimated using the proportion of mated males as an index of reproductive performance. We quantified landscape characteristics (cover types and fragmentation metrics) from digitized aerial photographs using Arcview® with the Patch Analyst© extension and measured microhabitat characteristics on spot-mapping plots.

Territory density of Cerulean Warblers was greater in intact (4.6 terr/10 ha) than fragmented forests (0.7 terr/10 ha), although mating success of males was similar in both (60%). Habitat models that included both landscape and microhabitat variables were the best predictors of territory density. The best model indicated that territory density increased with increasing snag density, percent canopy cover >6-12m and >24m, and distance from mine edge. Models for predicting microhabitat use at the territory level were weak, indicating that microhabitat characteristics of territories were similar to habitat available on spot-mapping plots. The species did not appear to avoid internal edges such as natural canopy gaps and open or partially-open canopy roads. Territory placement on ridges was greater than expected and in bottomlands (ravines) and west-facing slopes less than expected based on availability in both intact and fragmented forest. In fragmented forest, 92% of territories occurred only in fragments with ridgetop habitat remaining. Preference for ridges suggests that MTMVF may have a greater impact on Cerulean Warbler populations than other sources of forest fragmentation since ridges are removed in this mining process. Generally, our data indicate that Cerulean Warblers are negatively affected by mountaintop mining from loss of forested habitat, particularly ridgetops, and from degradation of remaining forests (as evidenced by lower territory density in fragmented forests and lower territory density closer to mine edges).

INTRODUCTION

The Cerulean Warbler (*Dendroica cerulea*), a species of concern in the eastern United States, occurs at high densities in southern West Virginia. Cerulean Warblers have been declining in many parts of their range (Sauer et al. 2000), and southwestern West Virginia may represent a significant source population for this species in the eastern United States (Rosenberg and Wells 2000). A recent status assessment by the U.S. Fish and Wildlife Service indicates that the population is declining at "precipitous rates" and that the primary threat to the species is loss of habitat (Hamel 2000). The assessment also suggests that successful management will depend upon managing high quality habitat in forested landscapes (Hamel 2000). It is estimated that 47% of the Cerulean Warbler population in North America occurs in the Ohio Hills physiographic area (Rosenberg 2000), which includes part of southern West Virginia. Partners in Flight (PIF) identified the Cerulean Warbler as priority species for conservation in the upland forest community of the Ohio Hills and Northern Cumberland Plateau physiographic areas (Rosenberg 2000, C. Hunter, personal communication), the 2 areas within which our study sites fall. This species also is listed as being at Action level II (in need of immediate management or policy range-wide) by PIF (Rosenberg 2000).

A current potential risk to Cerulean Warbler populations is the coal mining technique of mountaintop mining/valley fill (MTMVF). These extensive surface mines can impact areas on the order of 2000 ha in size, converting a landscape that is predominantly forested to a landscape of predominantly early successional habitats with remnant forest fragments (Wood et al. 2001). It is imperative to understand how these landscape-level changes could impact Cerulean Warblers, a species that inhabits large tracts of mature deciduous forest with large, tall trees (Hamel 2000). The species appears to use edges of small canopy gaps within large tracts; however, the use of openings and edges needs further study. Other high priority research needs include occurrence and density of this species relative to landscape characteristics, especially in relation to forest fragmentation, habitat preferences in relation to vegetation structure, and response of populations to land management activities (Hamel 2000).

Fragmentation and loss of forest habitat from a variety of human-induced disturbances are major issues in wildlife conservation due to negative effects on a number of wildlife species, including Cerulean Warblers. Because West Virginia is predominantly forested, it provides important habitat for forest interior songbird species that require large tracts of unbroken forest. Mountaintop mining/valley fill sets back successional stages, essentially converting large areas of mature hardwood forest to early successional habitat. Forested valleys located below the target coal seams and beyond the reach of the valley fills often appear vegetatively similar to nearby contiguous tracts of forest, but are partially surrounded by actively mined or reclaimed areas resulting in large amounts of edge habitat. These edges may attract known nest predators, such as American Crows (*Corvus brachyrhynchos*) and Blue Jays (*Cyanocitta cristata*), and a known nest parasite, the Brown-headed Cowbird (*Molothrus ater*), which may negatively affect songbird populations by reducing productivity (reviews by Yahner 1988, Paton 1994).

The current federal status assessment indicates that "habitat destruction, fragmentation, and modification on breeding and nonbreeding areas" are most likely responsible for the decline of this species (Hamel 2000). The major effect of MTMVF on Cerulean Warblers is the loss and fragmentation of forested habitat. Fragmentation may negatively affect forest-dwelling songbirds because of isolation effects, area effects, edge effects, and competitive species interactions (Finch 1991, Faaborg et al. 1995). In a forested landscape, fragmentation results from timber harvests, roads, powerlines, stand diversity, and natural canopy gaps. This is a much finer scale than occurs in agricultural areas, where forests appear as islands in a sea of crops and/or pastureland. Fragmentation in a forested landscape might be viewed as "internal" or soft fragmentation, whereas fragmentation in an agricultural landscape might be viewed as "external" or hard fragmentation (Hunter 1990). Fragmentation in an agricultural landscape is often permanent, but fragmentation in forested landscapes is usually temporary (Faaborg et al. 1995). Faaborg et al. (1995) suggested that the latter type of fragmentation is less severe to forest birds than permanent fragmentation, but nonetheless, "detrimental effects still exist." For example, Duguay et al. (2001) found that the number of Wood Thrush fledglings produced in clearcuts was less than in unharvested forest, but the number produced was still high enough to prevent the clearcuts from being sink habitat. Weakland et al. (2002) found that the abundance of some forest interior species declined after diameter-limit harvesting, but the abundance of most species was not affected when a large diameter-limit (>45cm) was used. There are no published studies documenting the effect of MTMVF on forest-dwelling songbirds as forests are lost and fragmented due to mining activities. Thus, it is unclear whether or not MTMVF acts as an internal or external fragmentation event to songbird species. The severity of the habitat loss/fragmentation will depend on whether MTMVF areas are re-forested or if they are allowed to remain in early stages of succession. Even when natural succession occurs on reclaimed MTMVF sites, it can be very slow due to soil compaction and lack of a seed bank. Non-timber post-mining land uses such as grazing or development will result in permanent fragmentation of forest habitats.

During 1999 and 2000, we quantified the effects of MTMVF on songbird populations (Wood et al. 2001). Using point count methodology, we found Cerulean Warblers at relatively high abundances in both intact (47 point count stations) and fragmented forest (36 point count stations). They were detected at 62% of intact forest point counts and at 44% of fragmented forest point counts. However, the number of fragmented forests that we were able to sample (8) was relatively low, and we did not sample a large range of different-sized fragments. Additionally, presence of an individual does not imply that it bred there (Van Horne 1983).

In 2001 and 2002, we re-sampled our existing study sites and quantified Cerulean Warbler density using territory mapping techniques. Territory mapping can be a more accurate and precise method of estimating bird abundance (Bibby et al. 1992) and allowed us to make inferences concerning the relationships between bird density and habitat and landscape variables. We also added study sites in additional forest fragments resulting from MTMVF to assess the effects of fragment size and edge type. We measured microhabitat characteristics in the field and landscape characteristics from aerial photographs and related these to Cerulean Warbler territory density. Our specific objectives were: (1) to compare Cerulean Warbler territory density and an index of reproductive success in forests fragmented by MTMVF mining with those in relatively intact blocks of forest in southern West Virginia, (2) to quantify landscape characteristics affecting Cerulean Warbler territory density, and (3) to quantify territory-level characteristics of Cerulean Warbler habitat.

METHODS

Study Sites

Our study sites were located in mature forest surrounding three mountaintop mine/valley fill complexes within three watersheds in Boone, Logan, Kanawha, and Fayette counties, West Virginia (Figs. 1-4). One mine complex (2003 ha) in Kanawha and Fayette counties was in the Ohio Hills physiographic province; the other two (1672 and 1819 ha) were in the Northern Cumberland Plateau. These sites were used in our previous study of the impact of MTMVF on terrestrial wildlife in 1999 and 2000 (Wood et al. 2001).

Intact forest sites were relatively large, unfragmented areas of forest that were undisturbed by mining activities but located near reclaimed MTMVF complexes, either within the same watershed as the reclaimed site or in an adjacent watershed. Although these sites were relatively contiguous forest, they did have some breaks in canopy cover from streams, roads, powerlines, and natural canopy gaps. Some intact forest sites were located in close proximity to MTMVF areas, but no intact forest site shared more than one edge with an MTMVF area. We defined fragmented forest as a tract of forest located within a MTMVF complex and primarily surrounded by reclaimed mine land. Because these tracts are often long, narrow peninsulas of forest, they generally are surrounded by reclaimed land on at least three sides.

The intact and fragmented forest areas are comprised mostly of mature hardwood species including oaks (*Quercus* spp.), hickories (*Carya* spp.), tuliptree (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*), red maple (*Acer rubrum*), sugar maple (*A. saccharum*), and white ash (*Fraxinus americana*). These stands are second growth forests that appeared to be approximately 60-80 years old. Although forested, these stands may have been periodically disturbed over the last several decades from firewood cutting, single tree harvesting, thinning, and understory forest fires.

Surveys/sampling

In 2001, we established six intact forest plots (two within each watershed) and 19 plots in 15 fragments. Two additional intact plots were added to the study in 2002.

We surveyed Cerulean Warblers using a territory-mapping technique called spot-mapping (Bibby et. al 1992). Plots were placed near the center of 15 forest fragments ranging from 1-290 ha, allowing us to examine territory density relative to fragment size. In 2 larger fragments, two 10 ha plots were established, 1 near the center and 1 adjacent to a reclaimed grassland mine edge to examine response to major edge type (Table 1). In the largest fragment, 3 plots were established, 1 adjacent to edge (10 ha), 1 interior on a mid-slope (7.5 ha), and 1 along a stream (10 ha). In fragments <10 ha in size, the whole fragment was surveyed for Cerulean Warblers; therefore plot size was equal to fragment size (Table 1). All intact forest plots were 10 ha in size. Although intact forest plots were at least 100 m from the mine edge, they still contained internal edges due to the presence of roads, streams, and natural canopy gaps, giving us the opportunity to assess the effects of these edge types on Cerulean Warbler densities.

Each fragmented forest and intact forest plot was surveyed at least 10 times from the first week of May to the first week of July each year (Bibby et al. 1992). Surveys were conducted from one-half hour after sunrise to 1030 hr EST. All surveys were conducted by 3-5 observers experienced in songbird identification and trained in territory-mapping procedures. The maximum number of territories/10 ha on each plot between years was used in statistical analyses.

Assessing Reproductive Success

Information on Cerulean Warbler reproductive success is greatly needed, but it was logistically unfeasible to find enough nests of this canopy-nesting species to have an adequate sample size needed to determine survival rates. Therefore to evaluate reproductive performance, we opportunistically gathered evidence of breeding, such as nest location and nestling food provisioning, and male/female interactions on each plot by observing Cerulean Warbler activity during territory mapping. Although these methods are limited, we believe they provided us with at least some information on the reproductive success of Cerulean Warblers within our study area. Vickery et al (1992) applied a similar method while studying sparrow species in Maine, for which they could find few nests. Researchers studying the Kirtland's Warbler (*D. kirtlandii*) (Probst and Hayes 1987), Ovenbirds (*Seiurus aurocapillus*), and Kentucky Warblers (*Oporornis formosus*) (Gibbs and Faaborg 1990) also used similar methods to estimate pairing success.

Microhabitat Sampling

We quantified microhabitat characteristics within each plot using modified methods from BBIRD (Martin et. al 1997) and James and Shugart (1970). We established two 0.04-ha quadrats per hectare in each territory-mapping plot. Quadrats were systematically distributed approximately every 50 m throughout the plot (Ratti and Garton 1994), except at sites that were used in our previous study in 1999-2000. We used existing microhabitat information from these sites (sampling methods were the same in both studies and habitat conditions had not changed) and only collected additional microhabitat measurements if the sample size was <2 quadrats/ha. One 0.04-ha quadrat was established at the center of each territory. Measurements included tree densities and diameters, density of snags >8 cm dbh (diameter-at-breast height), canopy height, aspect, percent slope, and percent canopy cover and ground cover as measured using an ocular tube (James and Shugart 1970). Snags were defined as standing dead trees >8 cm in diameter with no live foliage present.

We also determined the distance from the center of the territory to the closest edges using aerial photographs, compass, and pacing. Internal edge types included the following: open-canopy road, partially-open canopy road (including skidder trails), development (i.e. houses, buildings, etc.), river or stream, and natural canopy gap. Open-canopy roads were those that were not overtopped by trees and from which open sky was observed. Partially-open canopy roads were overtopped by trees and revealed little open sky. Natural canopy gaps were openings created by snags and/or windfalls. Mine edge was considered an external edge and was measured at the territory-level only when mine was the closest edge type. The mean of quadrat measurements for each variable for each plot was used in statistical analyses. Microhabitat measurements also were made at Cerulean Warbler nests using the methods described above.

Landscape Analyses

We quantified landscape characteristics by digitizing georeferenced copies of the 1996-97 National Aerial Photography Program (NAPP) photographs for our study areas into 7 land use/land cover categories: mature deciduous forest, mature mixed coniferous/deciduous forest, grassland, barren, shrub/pole, water/wetlands, and developed. Roads, trails, and streams were overlaid on cover maps to examine territory placement relative to these canopy gaps. Fragment size was measured from aerial photographs. Final maps were corrected to reflect changes since 1996. We used these maps to calculate the amount of each cover type within 1 km of the center of each study plot and to calculate fragmentation indices that may predict the density of Cerulean Warblers. Fragmentation indices included contrast-weighted edge density (Appendix 1), core area of mature forest, area of fragment or continuous forest (within 2-km of the plot center), and distance from mine edge. We used a 100-m buffer to calculate core area and edge density. Arcview® (Environmental Systems Research Institute 1996) with the Patch Analyst© extension (McGarigal and Marks 1994, Elkie et al. 1999) was used for all landscape analyses.

Statistical Analyses

Habitat models

To develop habitat models, we followed the recommendations of Burnham and Anderson (1998) who advocate an information-theoretic approach, which is based the principle of parsimony. This principle implies that a model should be as simple as possible with respect to the included variables, the model structure, and the number of parameters. They recommend the use of Kullback-Leibler information and Aikaike's information criterion (AIC) as the basis for modeling rather than null hypothesis testing. With this approach, one selects a set of candidate models prior to examining the empirical data. The *a priori* models are selected based on previous knowledge of the species in question. Variables are dropped or combined before modeling with the actual data. When little is known about the system in question, a large number of candidate models may be examined in an exploratory analysis. As Burnham and Anderson state, this method emphasizes thinking about the set of candidate models, excluding those variables that probably are not relevant to the species, and looking for potentially important variables in the literature. Models are evaluated by comparing relative AIC values among models and by examining Aikaike weights to determine the probability of each model being selected for the given data relative to all the others (Burnham and Anderson 1998).

Habitat available for Cerulean Warblers was evaluated 3 ways: at the microhabitat level (plot), landscape level, and the territory level. We began model selection at the microhabitat and landscape levels by first examining the frequency distribution of Cerulean Warbler territories, which was found to be a Poisson distribution (Neter et. al 1988). We then modeled the relationship between territories and habitat variables using Poisson regression (Stokes et al. 1995).

Microhabitat variables included in the candidate models were density of large trees (>38 cm dbh) and snags, distance from the closest edge, and canopy cover in 4 height classes (Table 2). We excluded understory stem densities, ground cover, and low canopy cover (<6 m) which likely have little influence on habitat selection by this canopy-dwelling species. Average canopy height also was excluded. Since Ceruleans are known to select the tallest trees as singing perches, we felt that including this variable would bias the results.

At the landscape level, variables were combined or excluded based on known preferences of the species or because they were highly correlated to one another. The area of mature deciduous forest was removed from the analysis because it was highly correlated to core area of mature forest. Cover of shrub/pole, grassland, wetlands/ponds, and barren were combined into one cover class (mine) to help reduce the overall number of variables in the model because the species is not likely to select any of these habitats. Landscape variables included in the candidate models were mine cover, mature mixed conifer/deciduous cover, development cover, as well as 4 fragmentation indices (Table 2).

Because little is known about Cerulean Warbler habitat use in West Virginia and there is no information regarding landscape effects from mountaintop removal on this species, we proceeded with an exploratory analysis and examined a large number of candidate models (n=488) using a top-down approach by starting with the full model and deleting variables (Burnham and Anderson 1998). The full model included all 14 microhabitat and landscape variables (Table 2). We then calculated AIC values with a correction factor (AIC_C), because our sample size to parameter ratio was <40 (Burnham and Anderson 1998). Models examined included all 14 univariate models, microhabitat-only models, landscape-only models, and combined models with both microhabitat and landscape variables.

To examine territory-level habitat use, we developed logistic regression models from use/non-use data with the same variables used in microhabitat analyses. Use data were measurements taken at the center of territories (primarily singing male core areas or nest sites). Non-use data were measurements taken on subplots that fell outside the areas used by singing males, as determined from spot-maps (Figs. 5-14). Two sets of logistic regression models were developed. The first used data from all vegetation subplots in all plots. The second used data only from plots where Cerulean Warblers were found, to exclude plots where Ceruleans may not have been detected because of the landscape. We selected the 5 best models from a set of 20 candidate logistic models initially developed from knowledge of Cerulean Warbler habitat preferences from the literature and from consulting with others who study this species. AIC_c values were used to select the 5 best models.

Comparisons between treatments

We used chi-square analysis (Zar 1999) to examine the difference between the used and available habitat in fragmented and intact forest. We then calculated Bonferroni 95% confidence intervals (Neu et al. 1974) for the proportion of occurrence in each habitat category and compared them to the available habitat.

Cerulean Warbler density relative to slope, aspect, and edges

Cerulean Warbler territory placement relative to slope position, aspect, and edges was examined using chi-square analysis (Zar 1999) and Bonferroni 95% confidence intervals (Neu et al. 1974). The occurrence of Cerulean Warbler territories in each category was determined by using the position of the center of the territory. Ninety-five percent confidence intervals were calculated to examine the difference between the proportion of occurrence and the proportion of available habitat in each category.

We measured the area of each spot-mapping plot that was ridge, mid-slope, and low-slope to determine the proportion available for each slope position. The expected number of territories in each category was determined by multiplying the total number of territories by the proportion of available habitat in each category. Ridge was considered the area of the plot at the peak with little or no slope. Low slope was the area of the plot that was at the foot of the slope <25 m from a stream or creek bottom. Mid slope was all the area between the low slope and the ridge. We determined the area of each plot that faced east (0-180º), and west (>180-359º), as well as the area in ridge top and bottomland that have no slope and thus no aspect. Aspects could not be broken down further because of small sample sizes.

We used chi-square (Zar 1999) to compare use and availability of edge types. Edge type use was the closest edge to each territory. We determined the availability of edge types using data from the non-use vegetation quadrats. The proportion of quadrats in each closest edge category was considered available edge habitat. The expected total number of territories was the product of the total number of observed territories and the proportion of edge types available in each edge category. We compared the proportion of edge types available between fragmented and intact forests using a paired t-test (Neter et al. 1988).

Mating success

We attempted to observe mating and reproductive behavior on all plots in 2001, and on a sub-sample of plots in 2002. Initially we planned to rank male reproductive success using the reproductive index score of Vickery et al. (1992). However, because these birds stay relatively high in the canopy, females are notoriously secretive, and few active nests were found, the reproductive index score was not effective for use with our data. However, we present findings for all males that were followed and observed for at least 60 min. Males were considered mated if a female was observed on the territory, the male was observed feeding fledglings, or the male sang the "whisper" song, which is only sung by mated males (J. Barg, pers. comm.). Males were considered unmated if they never sang the whisper song, females were never observed on the territory, fledglings were not observed, and the male had a high rate of singing.

RESULTS

Treatment Comparisons

We mapped 14 territories on 175.3 ha of fragmented forest in 2001 and 10 in 2002 (Figs. 5-11) for an average territory density of 0.7 territories/10 ha. In intact forest, we mapped 24 territories on 60 ha in 2001 and 40 on 80 ha in 2002 (Figs. 12-14) yielding a mean territory density of 4.6 territories/10 ha. The proportion of observed territories was less in fragmented forest and greater in intact forest than the proportion expected based on the habitat available in each treatment (Table 3, Fig. 15). Seventy-three percent of all territories were in intact forest, although only 28.5% of the total area surveyed was intact forest. Territory density was over 6 times higher in intact than fragmented forest.

Microhabitat and Landscape Models

The 5 best habitat models were combined models that included both microhabitat and landscape variables (Table 4). All 5 models included 3 microhabitat variables (percent canopy cover >6-12 m (Fig. 16), percent canopy cover >24 m (Fig. 17), and snag density (Fig. 18)) and the landscape variable distance from mine edge (Fig. 19) as predictor variables. All variables were positively related to Cerulean Warbler territory density. The best model had an Aikaike weight of

0.58 relative to the other 487 models, indicating that it had a 58% probability of being chosen given the data. The next best model had a much lower weight, of 0.09. Although distance from mine edge appeared to have a weak relationship with density when all distances were examined, a closer inspection of the data showed a strong relationship up to 500m from the mine (Fig. 19).

The best microhabitat model contained snag density, percent canopy cover >6-12 m, and percent canopy cover >24 m as predictor variables, but had a low weight (*w* <0.01) compared to the combined models. The best landscape model contained area of mature mixed conifer/deciduous forest and core area of mature forest (Fig. 20) as predictors but also had a very low weight (*w* <0.01). Area of fragment/continuous forest also was one of the better predictors (Fig. 21).

Territory-level Models

To identify microhabitat characteristics that Cerulean Warblers may use for placement of their territories within a plot, we developed logistic regression models comparing territory and available sites. The 5 best models developed from all plots and only from plots with Cerulean Warbler territories all had low Aikaike weights (Table 5) indicating that these variables are poor predictors of Cerulean Warbler territory placement. Means and standard errors for these variables indicate only a small difference between non-use subplots and territory subplots (Appendix 2), which may not be biologically significant.

Density relative to aspect, slope position, and edges

For all plots combined, ridge habitat use by Cerulean Warblers was greater than availability whereas mid slope habitat use was less than availability (Table 3, Fig. 22). The proportion of occurrence on low slopes did not differ from what was available. This trend was the same in both fragmented and intact forests (Table 3). Territory density was over twice as high on ridges than on low and mid slopes (Table 3).

The proportion of Cerulean Warbler occurrence was less than the proportion available on west-facing slopes and bottomlands and greater than what was available on ridges; it did not differ from what was available on east-facing slopes (Table 3). Again, this trend was similar between intact and fragmented forests. Density was twice as high on ridges than east-facing slopes and 4 times greater on ridges than west-facing slopes and bottomlands (Table 3).

When territories in fragmented and intact forest were combined, territory placement in relation to closest edge type was different from expected (χ^2=36.82, df=4, P<0.001) based on edges available on the territory-mapping plots (Table 6). Territories were adjacent to streams less than expected and adjacent to partially-open canopy roads greater than expected (Table 6). The distribution of closest edge types did not differ between fragmented and intact forest (t<0.01, df=4, P=1.00) (Fig. 23), so a similar pattern of selection was observed in each treatment. In both treatments, territories were adjacent to streams less than expected and adjacent to partially-open and open canopy roads greater than or equal to expected.

Most territories (63%) crossed either an open or partially-open canopy road/trail (Figs. 5-14). The mean distance to the closest internal edge was 30.3 m from a territory center and 34.4 m from a non-use subplot (Table 7). Both the logistic and the Poisson regression models showed a negative relationship between Cerulean Warbler territory presence/density and distance from closest edge indicating that they preferred areas closer to internal edges. Two territories in very small fragments were not included in analyses of closest internal edge because their closest edge was an external (mine) edge.

Mating Success

We were able to follow 10 males in fragmented forest (on 6 plots) and 30 males in intact forest (on 6 plots) in the 2 years of the study to determine mate status. Of the 10 males that were followed in fragmented forest, 60% were confirmed mated based on the presence of a female on the territory or observations of the male feeding fledglings, whereas 40% were assumed unmated, based on singing behavior and no observed female on the territory. Similarly, in intact forest, 60% of the 30 males observed were assumed to be mated based on observations of females with the male (30%) or because of "whisper singing" behavior (30%). Forty percent were assumed to be unmated. Males were observed feeding fledglings on 2 fragmented forest plots and 1 intact forest plot. One of these males was in one of the smaller fragments (9.4 ha), that had a considerable amount of edge habitat.

Four nests were found, 1 in 2001 and 3 in 2002. Three nests were in intact forest and 1 was in fragmented forest. One nest was successful, 2 were unsuccessful (possibly due to abandonment after severe weather), and 1 fate was unknown. Habitat characteristics around nest sites are summarized in Table 8. Nest tree species were northern red oak (*Quercus rubra*), tuliptree (*Liriodendron tulipifera*), american basswood (*Tilia americana*), and bitternut hickory (*Carya cordiformes*).

DISCUSSION

Our data indicate that loss and fragmentation of forests by MTMVF mining in southern West Virginia is negatively affecting populations of Cerulean Warblers. Cerulean Warbler territory density was lower in forests fragmented by mining than in intact forests. Both microhabitat and landscape components are important factors influencing territory densities.

Consistent predictors of territory density at the microhabitat level were percent canopy cover >6-12 m, >24 m, and snag density. Previous research indicates that Cerulean Warblers prefer a canopy divided into distinct vertical layers in flood plain forests of North Carolina, where tall, old-growth trees dominate the canopy (Lynch 1981). This bird typically nests at heights between 4.6-18.3 m (summarized in Hamel 2000), and thus it is not surprising that Cerulean Warbler territory density was higher in stands with a high amount of canopy cover from >6-12 m. Preference for areas with canopy cover >24 m is in agreement with studies that found this species in areas with large, tall trees and a dense upper canopy (Lynch 1981, Robbins et al. 1992, Oliarnyk 1996). Additionally, Hamel (2000) suggests that the vertical distribution of foliage may be more important than individual values of canopy cover at different heights. Thus, it is not surprising that canopy covers at 2 height classes were identified as predictors of Cerulean Warbler density.

The preference for a high density of snags is likely related to the apparent preference for areas with gaps in the canopy as noted by other researchers (Oliarnyk 1996, Oliarnyk and Robertson 1996). Snags likely contribute to the complex canopy structure apparently preferred by Ceruleans by opening the canopy allowing development of understory trees and by increasing heterogeneity of the canopy. Further, our data indicate that Cerulean Warblers in our study area are not avoiding internal edges. We often observed both males and females in or near canopy gaps, such as open and partially-open trails and roads and natural tree fall gaps. Two of the 4 nests we observed were within 10 m of a canopy gap (a natural tree fall gap and a partially-open canopy road).

Landscape factors also were significant predictors of Cerulean Warbler territory density. Distance from mine was positively related to density, particularly within 500 m (Fig. 19), indicating that Ceruleans are avoiding the large-scale edges produced by the mines. Cerulean density also was positively associated with core area of mature forest (Fig. 20) and area of fragment (Fig. 21), indicating a preference for large-blocks of mature forest similar to findings of Robbins et al. (1989) and Robbins et al. (1992). Density was negatively associated with area of mixed conifer/deciduous forest, which is primarily composed of Eastern hemlock. (*Tsuga canadensis*) on our study sites. This result also is not surprising given that this species is known to be restricted to mature deciduous forests (Hamel 2000).

Results at the territory level were inconclusive. Our data indicate that there was little difference in microhabitat between territories and non-use areas. It is possible that Cerulean

Warbler habitat is not limited within the mixed mesophytic forests of southwestern West Virginia and that suitable areas are not being occupied. Males may settle where others are already present and form loose "colonies" (Hamel 2000). If this is true, then Cerulean Warblers would exhibit a clumped distribution across the landscape, and it would appear that suitable habitat is not being used. Our data suggest that Cerulean Warblers may follow this pattern (Fig. 5-14). Single males occurred on only 3 plots where Cerulean Warblers were present.

Other studies identified large-diameter trees as being important for Cerulean Warblers (Robbins et al. 1992, Oliarnyk 1996, Hamel et al. 1994). We did not find tree diameter to be an important predictor of Cerulean Warbler occurrence. We often observed clusters of territories on ridges with "small" trees relative to tree size in other areas of the forest. Our data suggest that tree size may be less important for Cerulean Warblers in West Virginia than in other areas. Hamel (2000) suggested that tree diameters and heights may not accurately reflect Cerulean Warbler habitat and cannot be extrapolated among areas because these metrics are a function of topography, soils, and the site on which the forest is growing.

Both slope and aspect influenced Cerulean Warbler territory placement in our study. Territories were found more than expected on ridges. Brooks (1908) was the first to note the tendency of Cerulean Warblers to occupy breeding territories at or near the top of hills in West Virginia. Researchers in Indiana also have observed a similar trend in territory distribution (K. Islam, personal communication). Researchers with the Cerulean Warbler Atlas Project (CEWAP) in West Virginia also found Ceruleans to be more prevalent on dry slopes and ridges; approximately 65% of their sightings were in these areas (Rosenberg et. al 2000). Ridgetops may have structural features that attract Cerulean Warblers. Our data indicate that plots with ridgetops may have higher densities of snags (t=-2.57, df=21, P=0.01) than plots without ridges. Thus canopy gaps, which may be important for Ceruleans, likely are more prevalent on plots with ridges. However, neither canopy cover >6-12 m or >24 m differed between plots with ridges and those without ridges. More research is needed to determine the factors on ridges that attract Cerulean Warblers.

The preference for ridges could result in significant impacts on Cerulean Warbler populations in the MTMVF region. Because ridges are removed with this type of mining, Cerulean Warbler preferred habitat is lost. This could be one factor contributing to lower territory densities in forests fragmented by MTMVF mining. The majority of Cerulean Warbler territories in fragmented forest plots were on those that had ridges remaining. Of fragments without ridges, only 2 out of 7 had Cerulean Warbler territories (mean=0.17/10 ha), compared to 6 out of 8 with ridges that had Cerulean Warbler territories (mean=0.95/10 ha). On intact plots, those with ridges had a mean territory density of 6.0/10 ha compared to 0.80/10 ha on those without ridges. Analysis of point counts from our earlier study of MTMVF mining also indicates that Cerulean Warblers were found greater than expected at points on ridges (Weakland and Wood, unpub. data). Thus, continued removal of ridges in southern West Virginia by MTMVF mining could have serious negative effects on Cerulean Warbler populations.

The preference for placing territories on ridges also has implications for using BBS data for monitoring populations. Most BBS routes in this part of West Virginia are run primarily along valleys, where territory density is likely lowest; therefore density or abundance estimates based on BBS data are likely underestimates. However, we have found that Cerulean Warbler abundance at off-road point counts in West Virginia generally follows a similar pattern to BBS trends, although abundance estimates cannot be compared directly (Weakland et al. *in review*).

One limitation of our study was lack of information on breeding success. Although we anticipated difficulty in finding nests, we had expected the reproductive index of Vickery et. al (1992) to be more effective. Although we were not able to follow all of the males that we mapped on the plots, our data do provide some insight into reproductive performance. The proportion of mated males is likely to be an underestimate rather than an overestimate, since males we classified as unmated could have had a female that we did not detect. However, based on evidence of nesting and sightings of fledglings, it appears that Cerulean Warblers are breeding in both intact and fragmented forests in southern West Virginia and that the proportion of mated males (60%) is similar.

Researchers from Ontario who mistnetted males on our plots captured 5 males in fragmented forests and 14 in intact forest. In fragmented forests, 40% were second-year (SY; i.e. 1-year-old) males, and in intact forests, 21% were SY birds (K. Girvan, unpub. data). Although the data are limited, they suggest that Cerulean Warblers are breeding successfully in this area, but SY birds may be displaced into fragmented forests, which may be less suitable habitat.

SUMMARY

In conclusion, both landscape and microhabitat factors are influencing Cerulean Warbler density in southern West Virginia. Cerulean Warblers appear to prefer ridgetops within large blocks of mature forest with a high percent canopy cover from >6-12m and >24m, and a high density of snags. They do not appear to be avoiding internal (soft) edges such as roads and trails, but do appear to be avoiding the external (hard) edges created by mining. Generally, MTMVF mining reduces the amount of forested habitat available for use by Cerulean Warblers and is lowering the suitability of the remaining forest habitat as evidenced by lower territory density in fragmented forest and near mine edges. Because of the large size of most MTMVF areas, it is possible that they may have negative effects on populations of the Cerulean Warbler that require large blocks of unfragmented forest for breeding. Loss of ridgetop habitat appears to be particularly important in reducing territory density. The 3 MTMVF complexes on our study areas totaled 7,244 ha with approximately 76% in grassland habitat, 14% shrub/pole, and 10% fragmented forest (Wood et al. 2001). If we assume that this area was approximately 80% intact forest before mining, take into account that some fragmented forest remained after mining, and use a mean territory density of 4.6 territories/10ha in intact forest and 0.7 territories/10ha in fragmented forest, then potentially 2,625 Cerulean Warbler males could have been displaced by these 3 mines. However, at this point we do not know if nesting success differs between intact and fragmented forests or among different slope positions. So, although territory density may be higher in intact forest and on ridgetops, fledging success may not necessarily be higher than other areas.

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Table 1. Mine sites, treatments, study plots, and size of plots used to map Cerulean Warbler territory densities in southern West Virginia in 2001 and 2002.

Treatment	Mine	Site	# of Plots	Plot sizes (ha)	Forest Size (ha)[a]
Fragmented	Cannelton	Center A	1	8.6	8.6
		Center B	1	9.4	9.4
		Center C	2	10.0	36.0
		Jim Hollow/Hughes Fork	3	7.5, 10.0, 10.0	290.5
	Daltex	Hurricane	1	10.0	48.5
		Beech Creek	1	10.0	15.9
		Jenny	2	10.0	20.5
		Monclo	1	19.7	19.7
		Warehouse #1	1	1.0	1.0
		Warehouse #2	1	2.8	2.8
	Hobet	Lavender Fork	2	10.0,10.0	153.8
		Big Horse Creek	2	10.0,10.0	113.6
		Stanley Fork East	1	11.6	11.6
		Stanley Fork North	1	9.7	9.7
		Stanley Fork West	1	5.0	23.9
		Total	**21**	**175.3**	
Intact	Cannelton	A	1	10.0	1079
		B	1	10.0	752
		C	1	10.0	926
	Daltex	Pigeonroost A	1	10.0	1177
		Pigeonroost B	1	10.0	1211
		Oldhouse Branch	1	10.0	828
	Hobet	Ballard Fork	1	10.0	789
		Spring Branch	1	10.0	930
		Total	**8**	**80.0**	

[a] Forest size for fragments is the actual size of the fragment and for intact forest it is area of continuous forest within 2-km of the plot center.

Table 2. Microhabitat and landscape variables used to model the territory density of Cerulean Warblers in southern West Virginia.

Variables	Code
Microhabitat	
Percent Canopy Cover:	
>6-12 m	CC6-12m
>12-18 m	CC12-18m
>18-24 m	CC18-24m
>24 m	CC24m
Density of trees >38 cm dbh	Trees38cm
Density of snags >8 cm dbh	Snags
Distance to closest edge	DstEdge
Landscape	
Area of:	
Reclaimed mine	Mine
Mature mixed conifer/deciduous	MatMix
Development	Devel
Contrast-weighted edge density	CWED
Core area of mature forest	CoreArea
Area of fragment/continuous forest	ForArea
Distance to mine	DstMine

Table 3. Occurrence and density of Cerulean Warbler territories in fragmented and intact forests, at different slope positions, and aspects in southwestern West Virginia.

Test	Total ha	Prop. of total ha (p_{io})	No. CERW Observed	No. CERW Expected	Prop. of observed in each area (p_i)	95% Confidence Interval for p_i^a Lower	Upper	χ^2	df	*P*-value	Territories /10ha
Treatments											
Fragmented	350.6	0.715	24	63	0.273	0.180	0.366	84.98	1	<0.01	0.7
Intact	140	0.285	64	25	0.727	0.634	0.820				4.6
Slope Position											
All Plots											
Low	32.2	0.066	5	6	0.055	-0.002	0.112	37.33	2	<0.001	1.6
Mid	344.4	0.702	39	62	0.440	0.315	0.564				1.1
Ridge	114	0.232	44	20	0.505	0.380	0.631				3.9
Fragmented Forest											
Low	19.2	0.055	1	1	0.040	-0.009	0.089	5.64	2	<0.10	0.5
Mid	252.4	0.720	12	17	0.480	0.355	0.605				0.5
Ridge	79	0.225	11	6	0.440	0.316	0.564				1.4
Intact Forest											
Low	13	0.093	4	6	0.076	0.009	0.142	23.32	2	P<0.001	3.8
Mid	92	0.657	26	58	0.394	0.272	0.516				2.8
Ridge	35	0.250	34	22	0.500	0.375	0.625				9.4
Aspect											
All Plots											
East	198.8	0.405	37	36	0.407	0.278	0.535	48.45	3	P<0.001	1.9
West	145.6	0.297	5	26	0.055	-0.005	0.115				0.3
Ridge	114	0.232	45	20	0.484	0.352	0.614				3.9
Bottom	32.2	0.066	1	6	0.022	-0.016	0.060				0.6

Fragmented Forest											
East	136.8	0.390	12	9	0.480	0.349	0.611	12.29	3	<0.01	0.9
West	115.6	0.330	1	8	0.040	-0.011	0.091				0.1
Ridge	79	0.225	11	6	0.440	0.310	0.570				1.4
Bottom	19.2	0.055	0	1	0.000	0.000	0.000				0.0
Intact Forest											
East	62	0.443	25	28	0.379	0.252	0.506	28.19	3	P<0.001	4.0
West	30	0.214	4	14	0.061	-0.002	0.123				1.3
Ridge	35	0.250	34	16	0.500	0.369	0.631				9.4
Bottom	13	0.093	1	6	0.030	-0.015	0.075				1.5

[a] p_i represents the theoretical proportion of occurrence and is compared to corresponding p_{io} to determine if the hypothesis of proportional use is accepted or rejected (Neu et al. 1974).

Table 4. Independent variables for the 5 best combined, microhabitat, and landscape Poisson regression models used to predict Cerulean Warbler territory density in southern West Virginia, with their AIC_C values, Δ AIC_C values, Aikaike weights (*w*), and rank (out of 488 models). The '+' and '-' signs before each variable indicate the direction of the relationship between the variable and territory density.

Models	AIC_C	Δ	*w*	Rank
Combined				
+CC6-12m, +CC24m, +Snags, +DstMine	-38.46	0.00	0.58	1
+CC6-12m, +CC24m, +Snags, +DstMine, -MatMix	-34.64	3.82	0.09	2
+CC6-12m, +CC24m, +Snags, +DstMine, +CoreArea	-34.34	4.12	0.07	3
+CC6-12m, +CC24m, +Snags, +DstMine, +FragArea	-32.89	5.56	0.04	4
+CC6-12m, +CC24m, +Snags, +DstMine, +Devel, -MatMix	-32.75	5.71	0.03	5
Microhabitat				
+CC6-12m, +CC24m, +Snags	-26.31	12.14	<0.01	36
+CC6-12m, +CC24m, +Snags, -DstEdge	-25.34	13.12	<0.01	41
+CC6-12m, +CC24m, +Snags, +Trees38cm	-24.94	13.52	<0.01	46
+CC6-12m, +CC24m, +Snags, +Trees38cm, -DstEdge	-24.16	14.30	<0.01	52
+CC6-12m, +CC24m, +Snags, -CC12-18, +Trees38cm	-24.13	14.33	<0.01	53
Landscape				
-MatMix, +CoreArea	-22.62	15.84	<0.01	59
-MatMix, +CoreArea, +DstMine	-21.75	16.71	<0.01	60
-MatMix, +CoreArea, -Mine	-21.64	16.81	<0.01	62
-MatMix, +CoreArea, -Mine, +Devel	-19.96	18.49	<0.01	80
-MatMix, +FragArea	-19.75	18.71	<0.01	82

Table 5. The 5 best microhabitat logistic regression models used to predict Cerulean Warbler presence in southern West Virginia, with their AIC_C values, Δ AIC_C values, and Aikaike weights (*w*). The '+' and '-' signs before each variable indicate the direction of the relationship between the variable and territory density.

Models	AIC_C	Δ	*w*
All plots			
+CC18-24m	467.18	0.00	0.15
+Snags	467.75	0.57	0.11
+CC18-24m, +Snags	467.81	0.63	0.11
-DstEdge	468.35	1.17	0.08
+CC24m	468.48	1.30	0.08
Only plots with Cerulean Warblers			
+CC18-24m	413.99	0.00	0.13
-DstEdge	414.00	0.01	0.13
+Snags	414.09	0.10	0.12
+CC12-18m	414.19	0.19	0.12
+Trees38cm	414.84	0.85	0.08

Table 6. Occurrence of Cerulean Warblers (CERW) adjacent to different closest internal edge types in southwestern West Virginia.

Test/Edge types	Availability: Number quadrats	Availability: Proportion (p_{io})	CERW Expected	CERW Observed	Prop. of Observed (p_i)	95% Confidence Interval for p_i[a]: Lower	95% Confidence Interval for p_i[a]: Upper		χ^2	df	P-value
All Plots											
Natural gap	33	0.084	7	10	0.120	0.029	0.212	=[b]	36.82	4	<0.001
Stream	138	0.352	29	5	0.060	-0.007	0.127	<			
Partially open road	125	0.319	26	40	0.482	0.341	0.623	>			
Open road	79	0.202	17	27	0.325	0.193	0.457	=			
>2 Types	17	0.043	4	1	0.012	-0.019	0.043	=			
Fragmented forest											
Natural gap	13	0.052	1	1	0.048	-0.072	0.167	=	18.95	4	<0.001
Stream	98	0.390	8	1	0.048	-0.072	0.167	<			
Partially open road	79	0.315	7	16	0.762	0.523	1.000	>			
Open road	49	0.195	4	3	0.143	-0.053	0.339	=			
>2 Types	12	0.048	1	0	0.000	0.000	0.000	<			
Intact forest											
Natural gap	20	0.142	9	9	0.145	0.030	0.260	=	21.50	4	<0.001
Stream	40	0.284	18	4	0.065	-0.016	0.145	<			
Partially open road	46	0.326	20	24	0.387	0.228	0.546	=			
Open road	30	0.213	13	24	0.387	0.228	0.546	>			
>2 Types	5	0.035	2	1	0.016	-0.025	0.057	=			

[a] p_i represents the theoretical proportion of occurrence and is compared to corresponding p_{io} to determine if the hypothesis of proportional use is accepted or rejected (Neu et al. 1974).

[b] Symbols indicate use equals availability (=), use less than availability so avoids (<), and use greater than availability so prefers (>).

Table 7. Mean distance (m) of Cerulean Warbler territory centers (n=83) and non-use subplot centers (n=392) from the closest internal edge in fragmented forests, intact forests, and combined forests in southern West Virginia.

	Fragmented Forest				Intact Forest				Combined			
	Non-use		Territory		Non-use		Territory		Non-use		Territory	
Edge Types	n	Mean	n	Mean	n	Mean	n	Mean	n	Mean	n	Mean
Natural Gap	13	27.3	1	50.0	20	18.5	9	14.3	33	22.0	10	17.9
Stream	98	32.0	1	15.0	40	28.5	4	27.5	138	31.0	5	25.0
Partially-open canopy road	79	20.1	16	12.5	46	22.6	24	20.0	125	21.0	40	17.0.
Open-canopy road	49	77.1	3	68.3	30	42.2	24	54.4	79	63.8	27	55.9
More than one type	12	39.2	0	--	5	68.0	1	20.0	17	47.6	1	20.0
Any edge	251	37.1	21	22.4	141	29.5	62	33.0	392	34.4	83	30.3

Table 8. Means and standard errors (SE) of microhabitat variables surrounding nests of Cerulean Warblers (n=3) in southern West Virginia.

Variables	Mean	SE	Range
Aspect Code	0.9	0.5	0.5-1.8
Slope (%)	47.3	1.9	45-51
Distance to closest edge (m)	20.0	10.4	5-40
Nest Height (m)	15.8	3.3	9-20
Stem Density (no./ha)			
<2.5 cm	6916.7	2387.4	2625-10875
>2.5-8 cm	541.7	150.2	250-750
>8-23 cm	408.3	93.9	250-575
>23-38 cm	141.7	65.1	25-250
>38 cm	116.7	104.4	0-325
Snags >8 cm	241.7	41.7	200-325
Canopy Cover (%)			
>0.5-3 m	13.3	7.3	0-25
>3-6 m	25.0	11.5	5-45
>6-12 m	31.7	16.4	0-55
>12-18 m	36.7	18.6	0-60
>18-24 m	45.0	13.2	25-70
>24 m	30.0	16.1	5-60

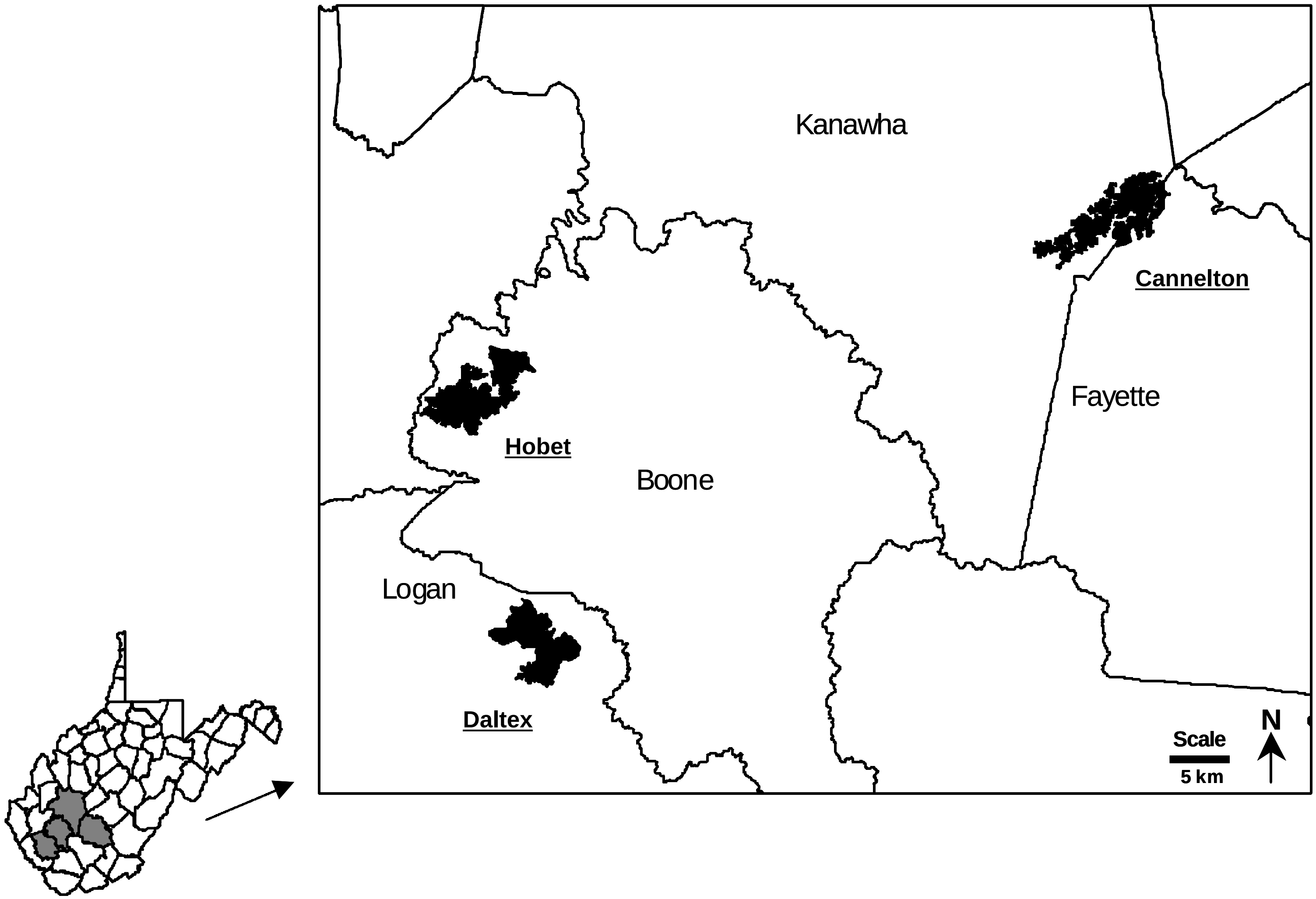

Figure 1. Location of the Hobet, Daltex, and Cannelton mountaintop mine complexes in southern West Virginia.

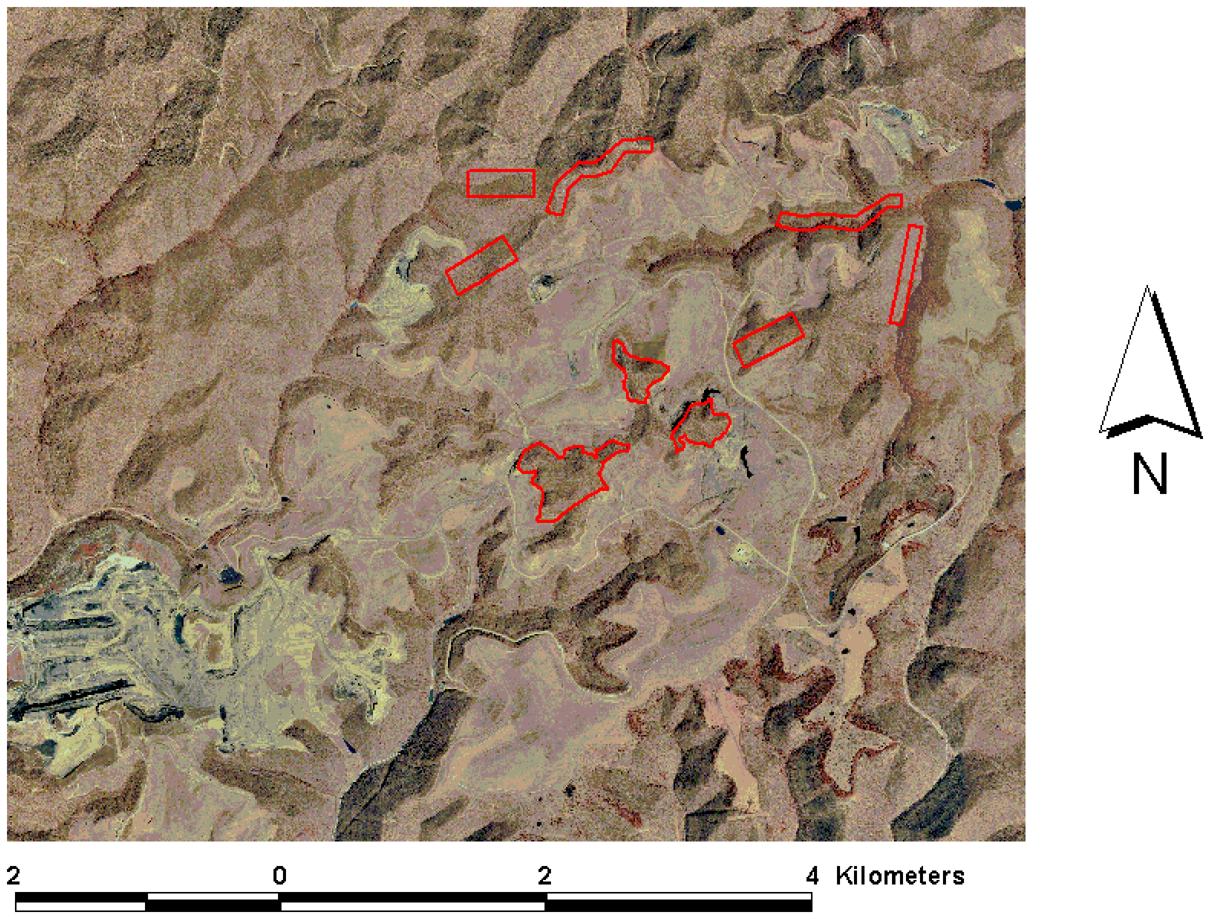

Figure 2. Aerial photo showing the location of study plots on and near the Cannelton mine complex. Plot boundaries are in red.

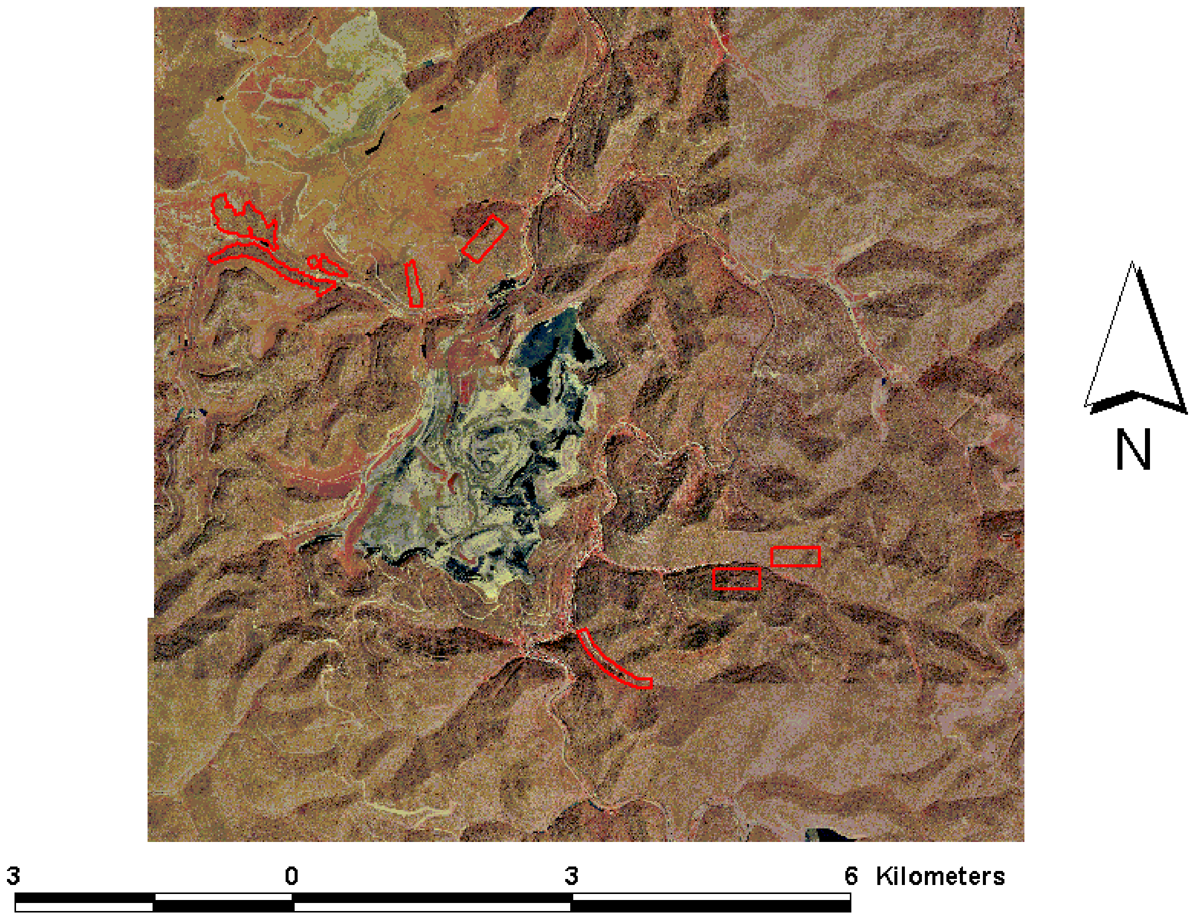

Figure 3. Aerial photo showing the location of study plots on and near the Daltex mine complex. Plot boundaries are in red.

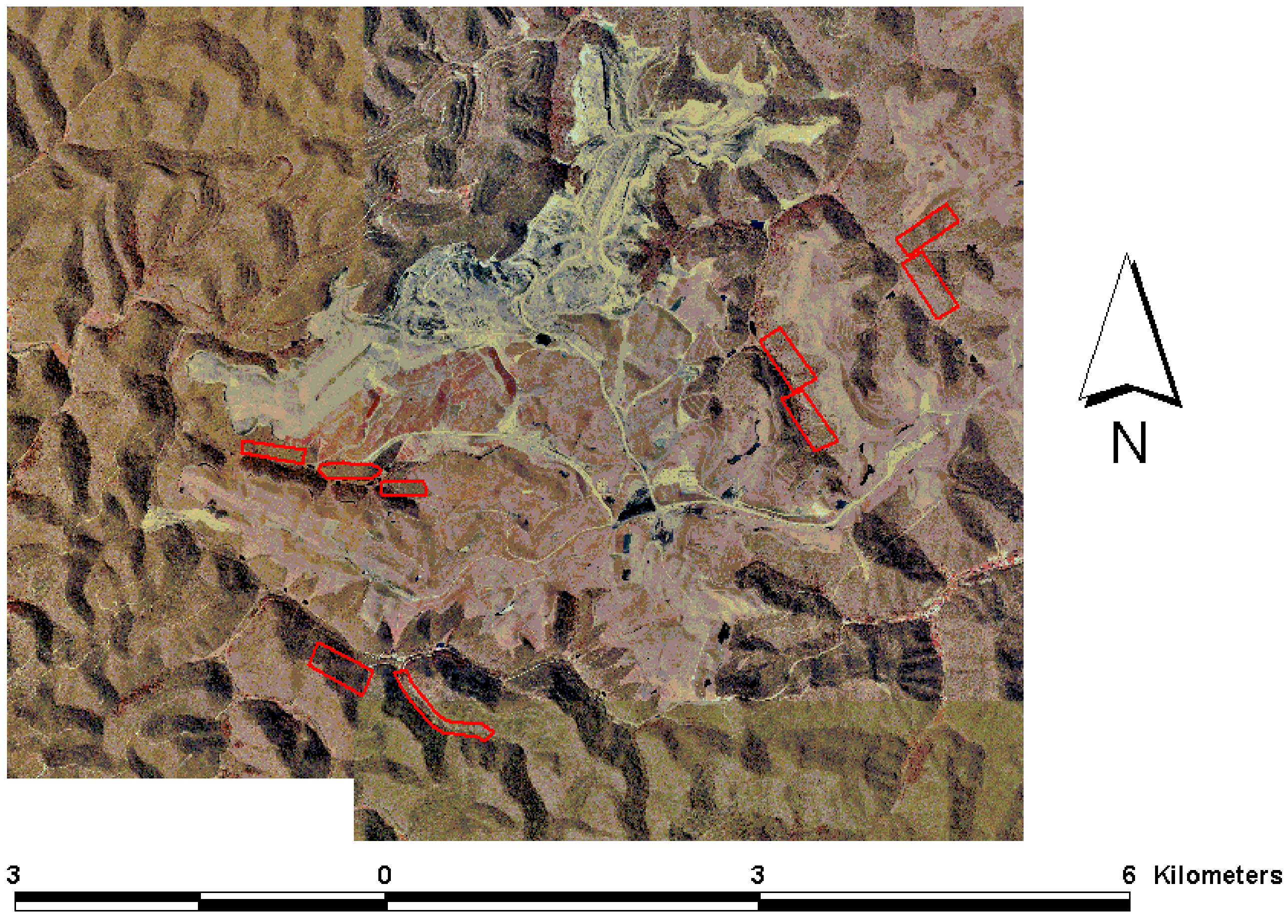

Figure 4. Aerial photo showing the location of study plots on and near the Hobet mine complex. Plot boundaries are in red.

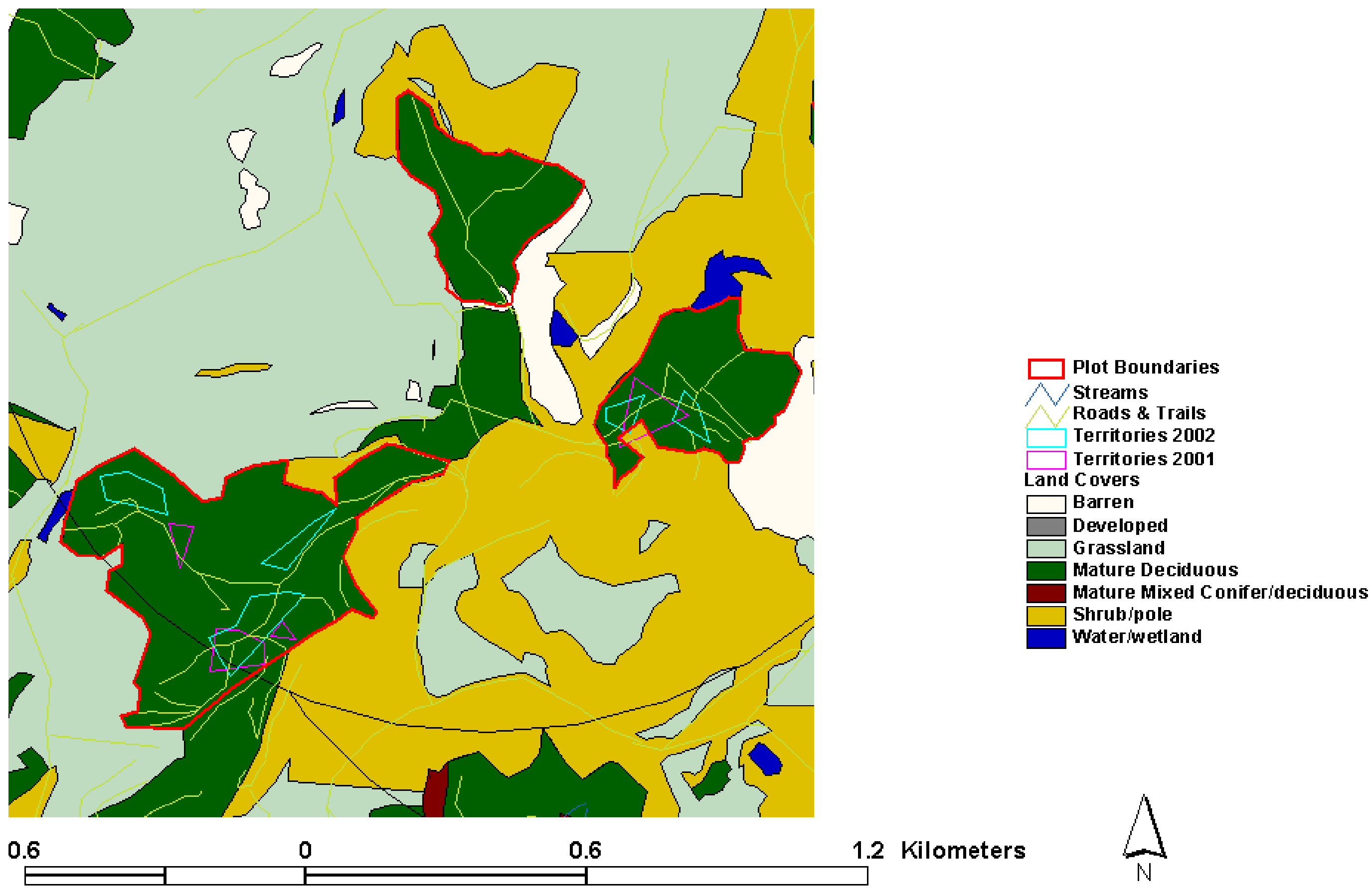

Figure 5. Fragmented forest plots and Cerulean Warbler territories in 2001 and 2002 at the Cannelton Mine.

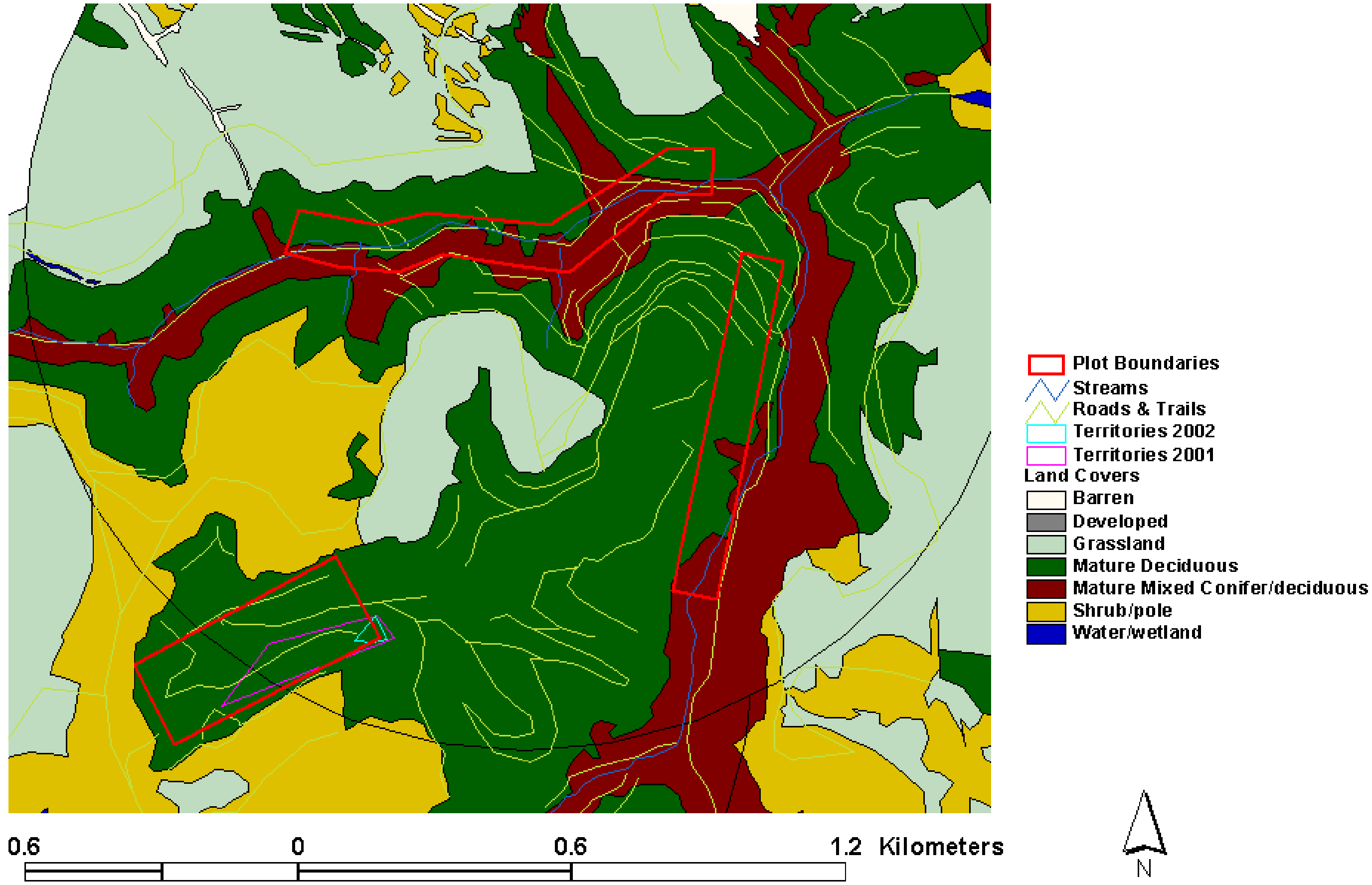

Figure 6. Fragmented forest plots and Cerulean Warbler territories in 2001 and 2002 at the Cannelton Mine.

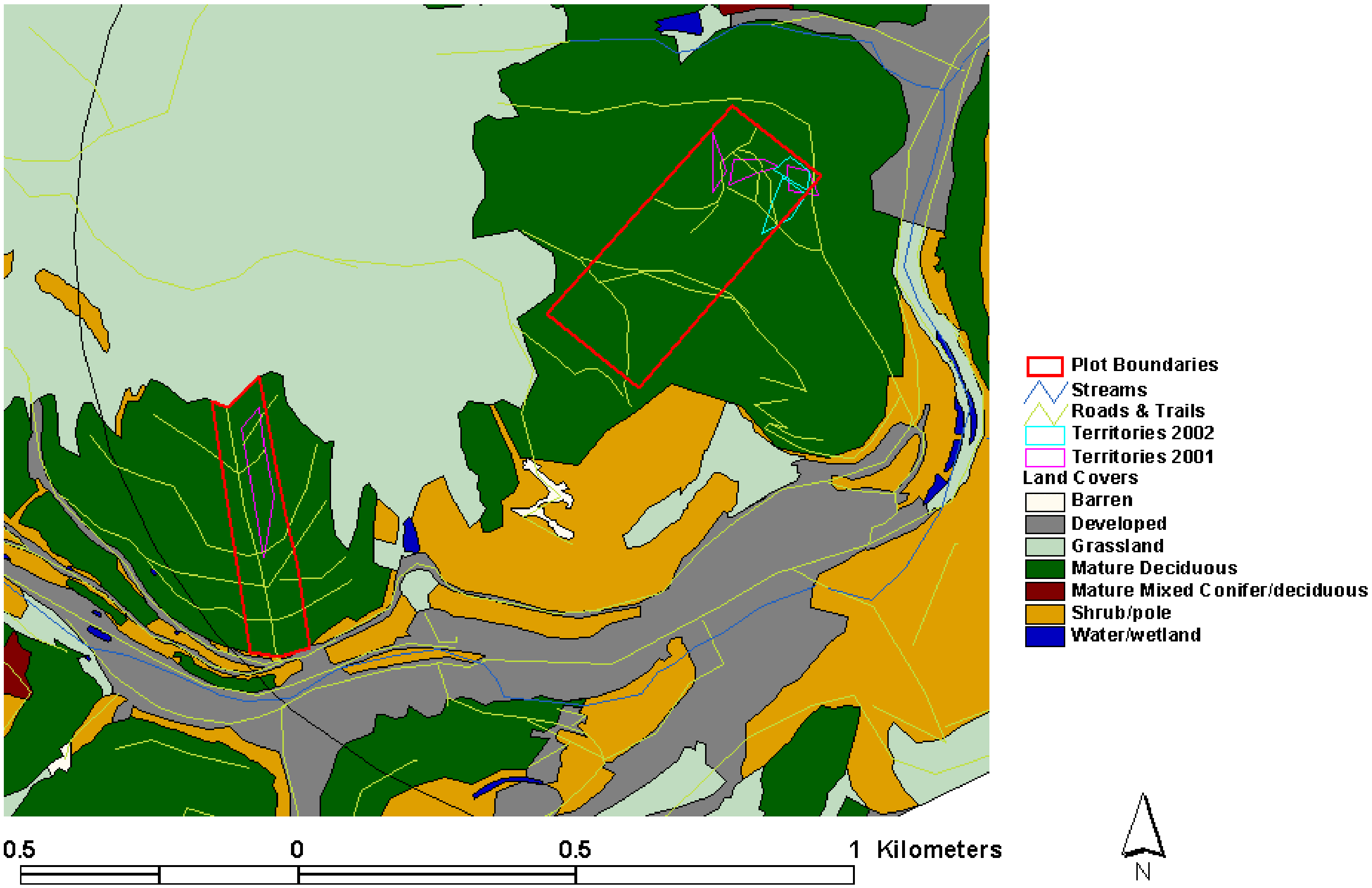

Figure 7. Fragmented forest plots and Cerulean Warbler territories in 2001 and 2002 at the Daltex Mine.

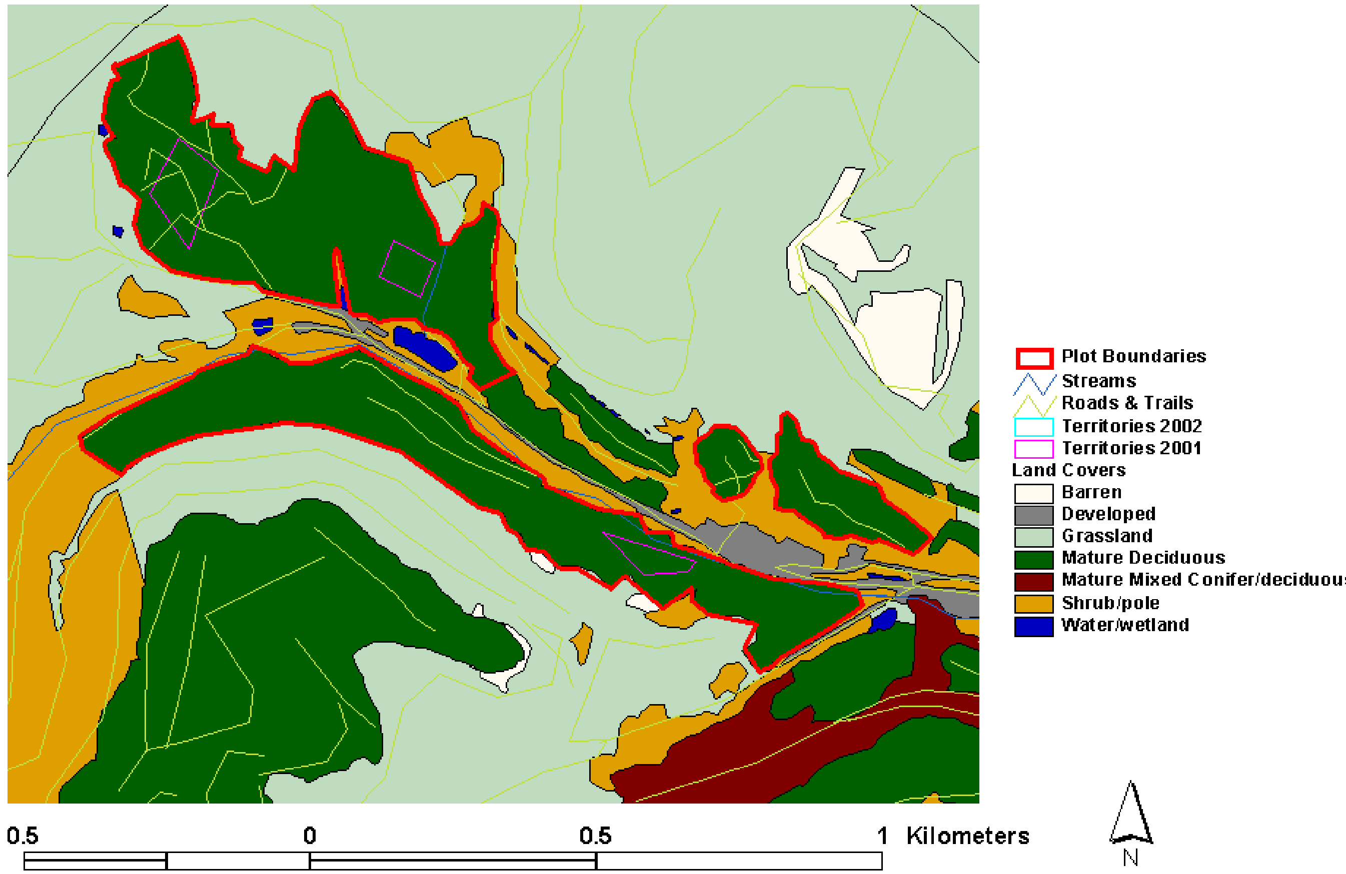

Figure 8. Fragmented forest plots and Cerulean Warbler territories in 2001 and 2002 at the Daltex Mine.

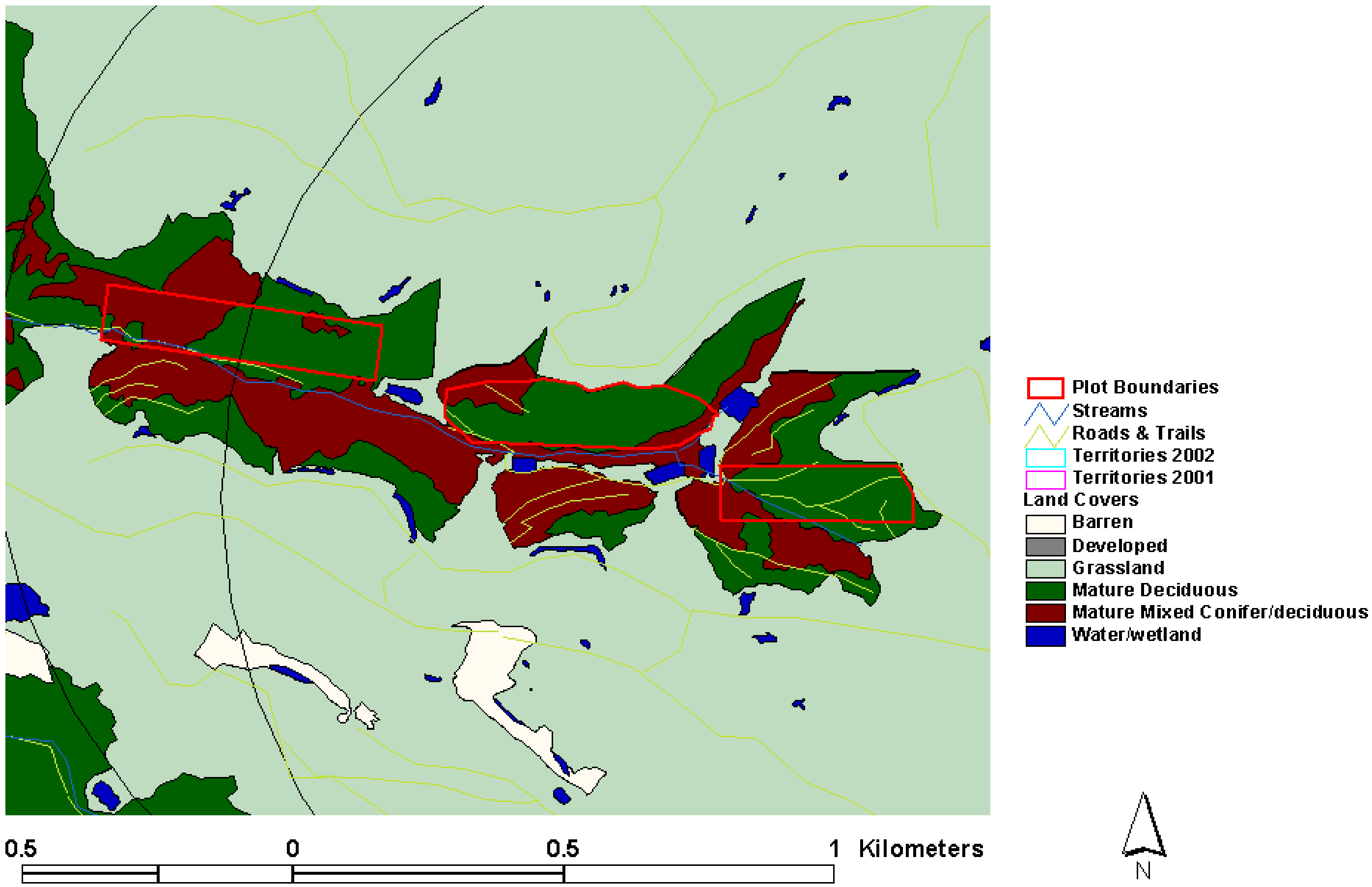

Figure 9. Fragmented forest plots and Cerulean Warbler territories in 2001 and 2002 at the Hobet Mine.

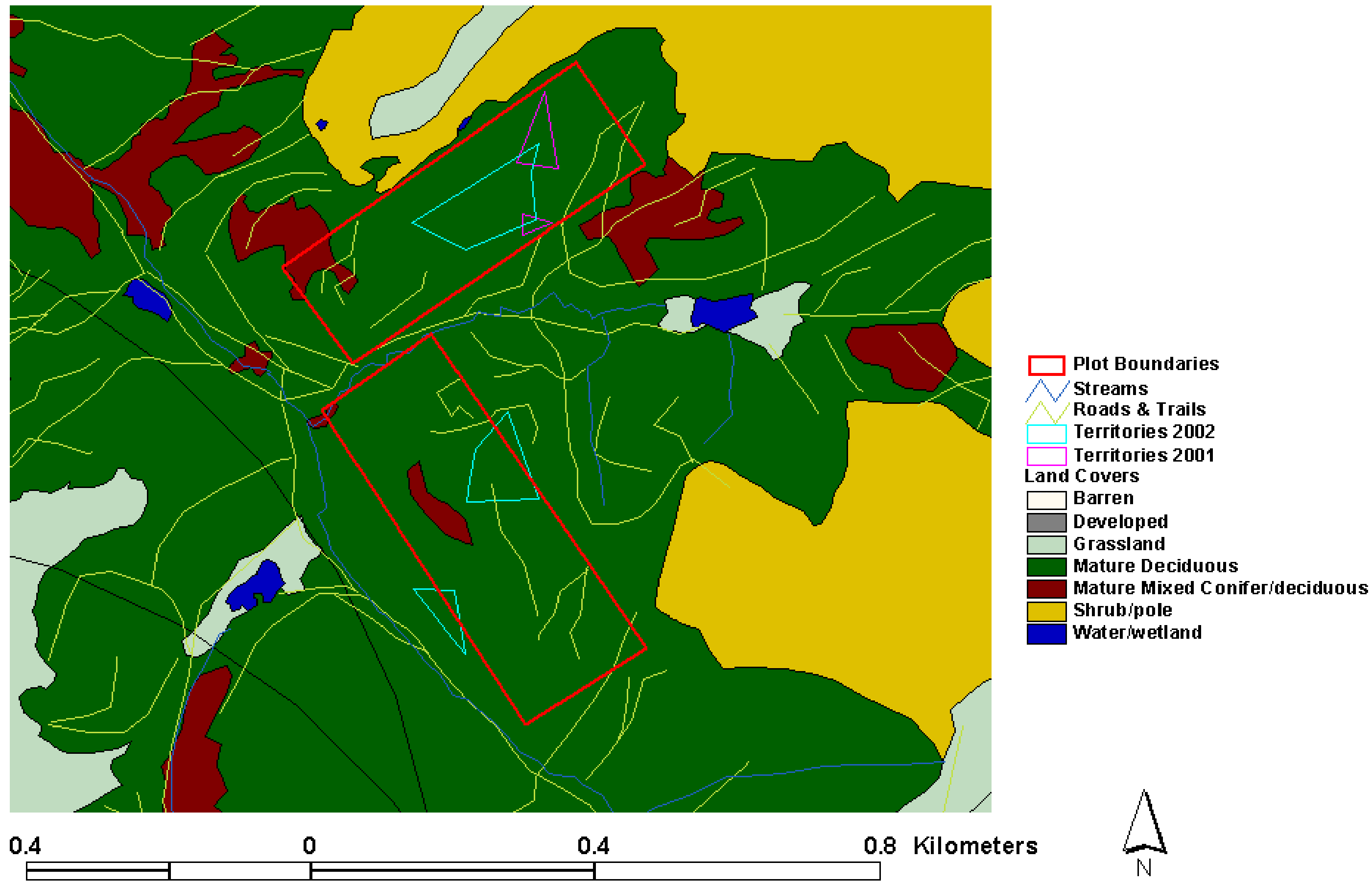

Figure 10. Fragmented forest plots and Cerulean Warbler territories in 2001 and 2002 at the Hobet Mine.

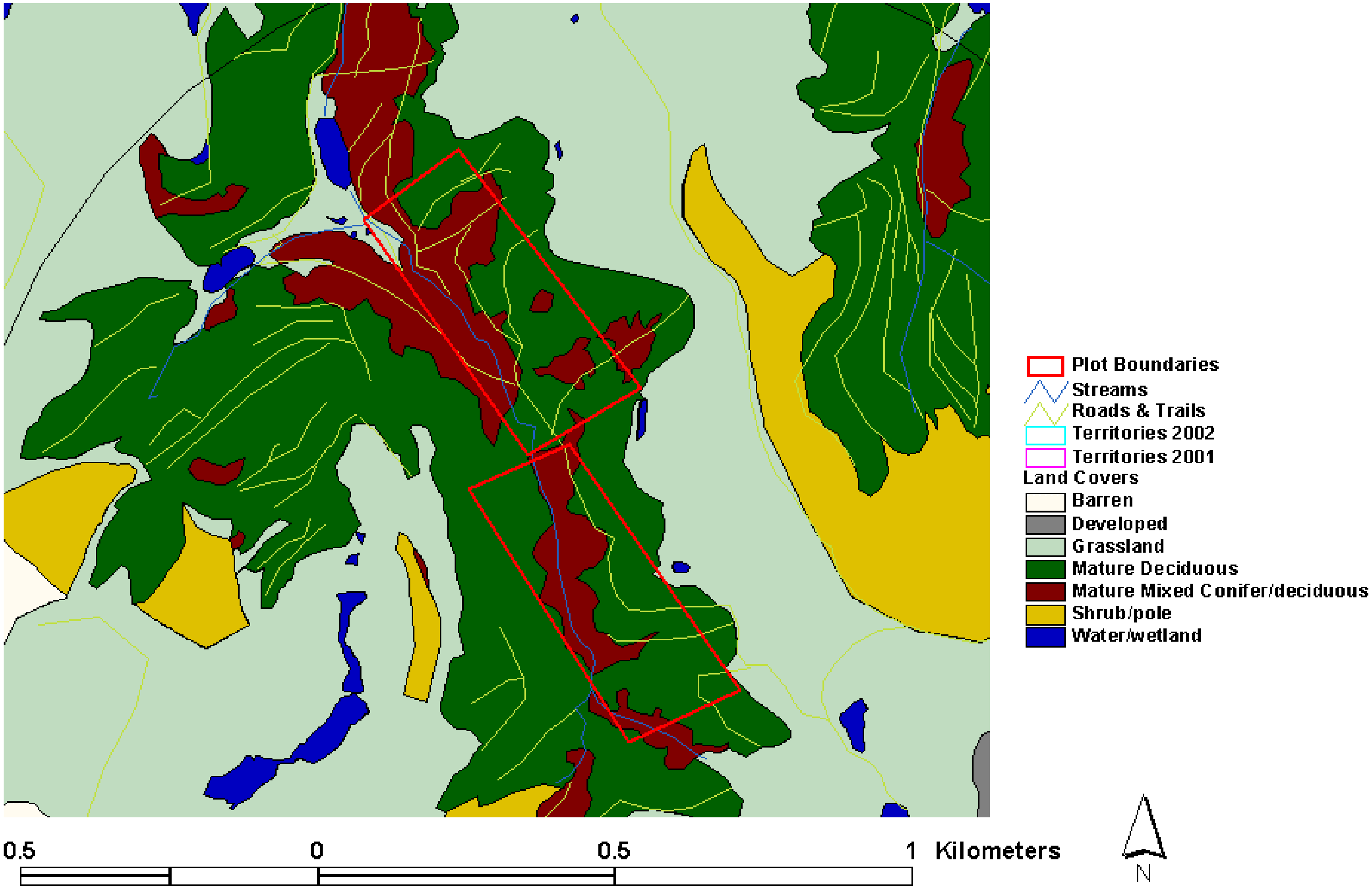

Figure 11. Fragmented forest plots and Cerulean Warbler territories in 2001 and 2002 at the Hobet Mine.

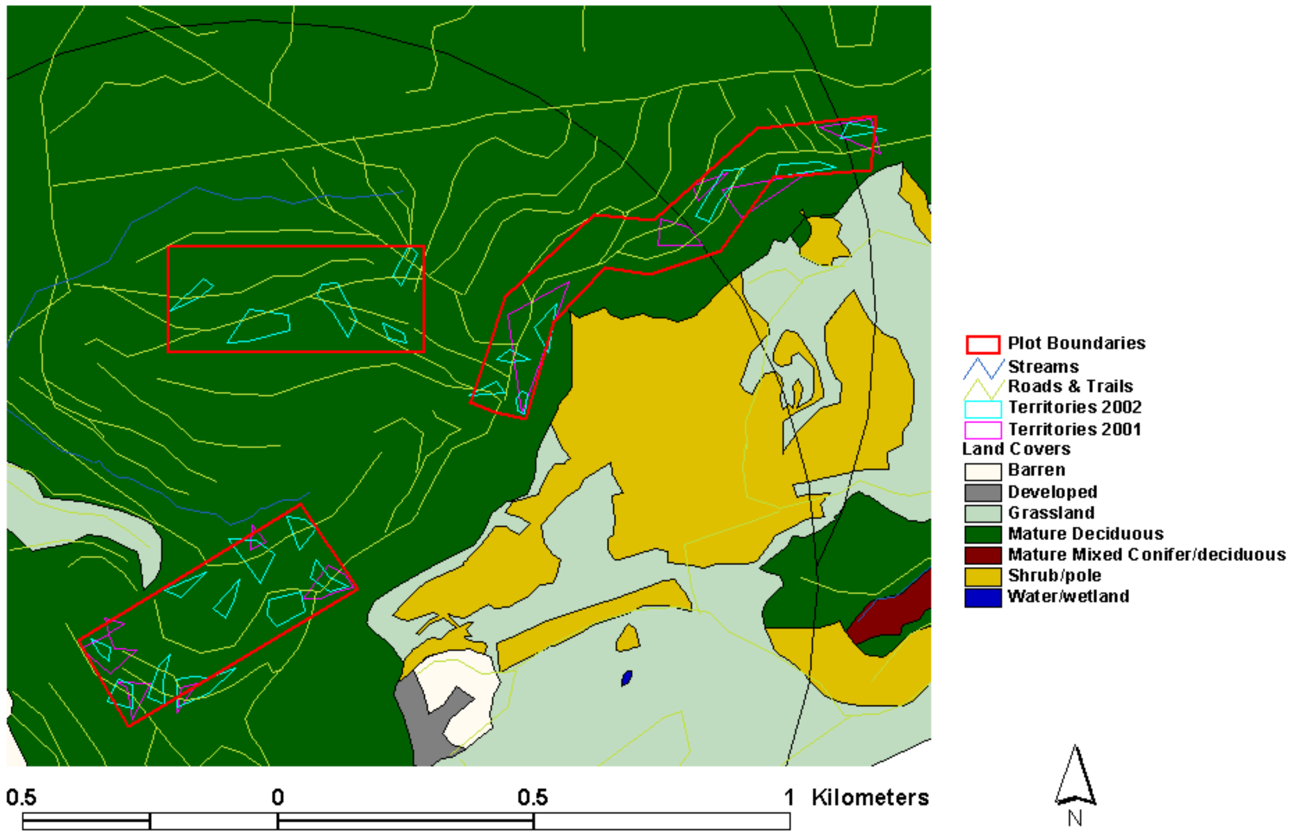

Figure 12. Intact forest plots and Cerulean Warbler territories in 2001 and 2002 at the Cannelton Mine.

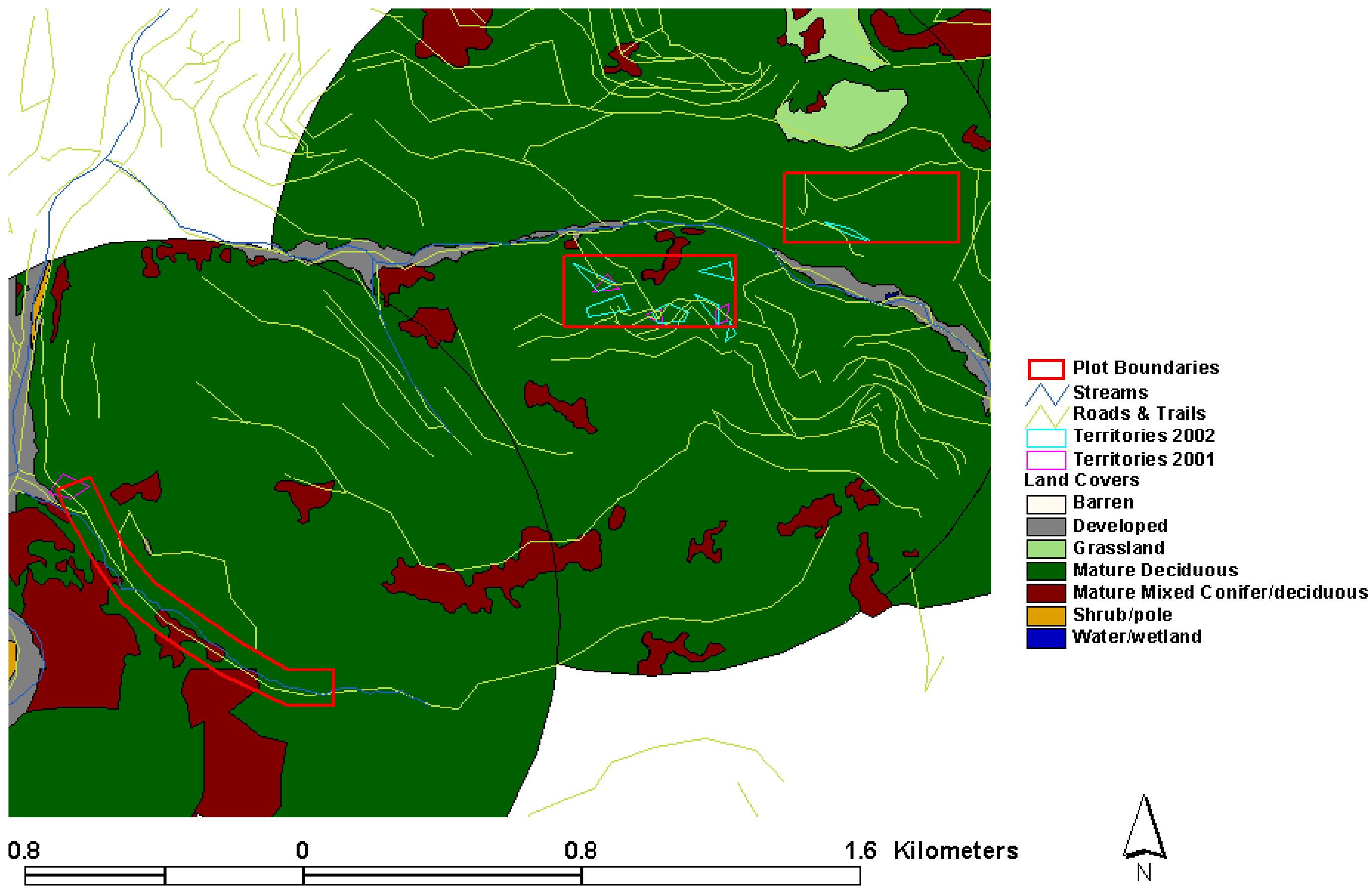

Figure 13. Intact forest plots and Cerulean Warbler territories in 2001 and 2002 at the Daltex Mine.

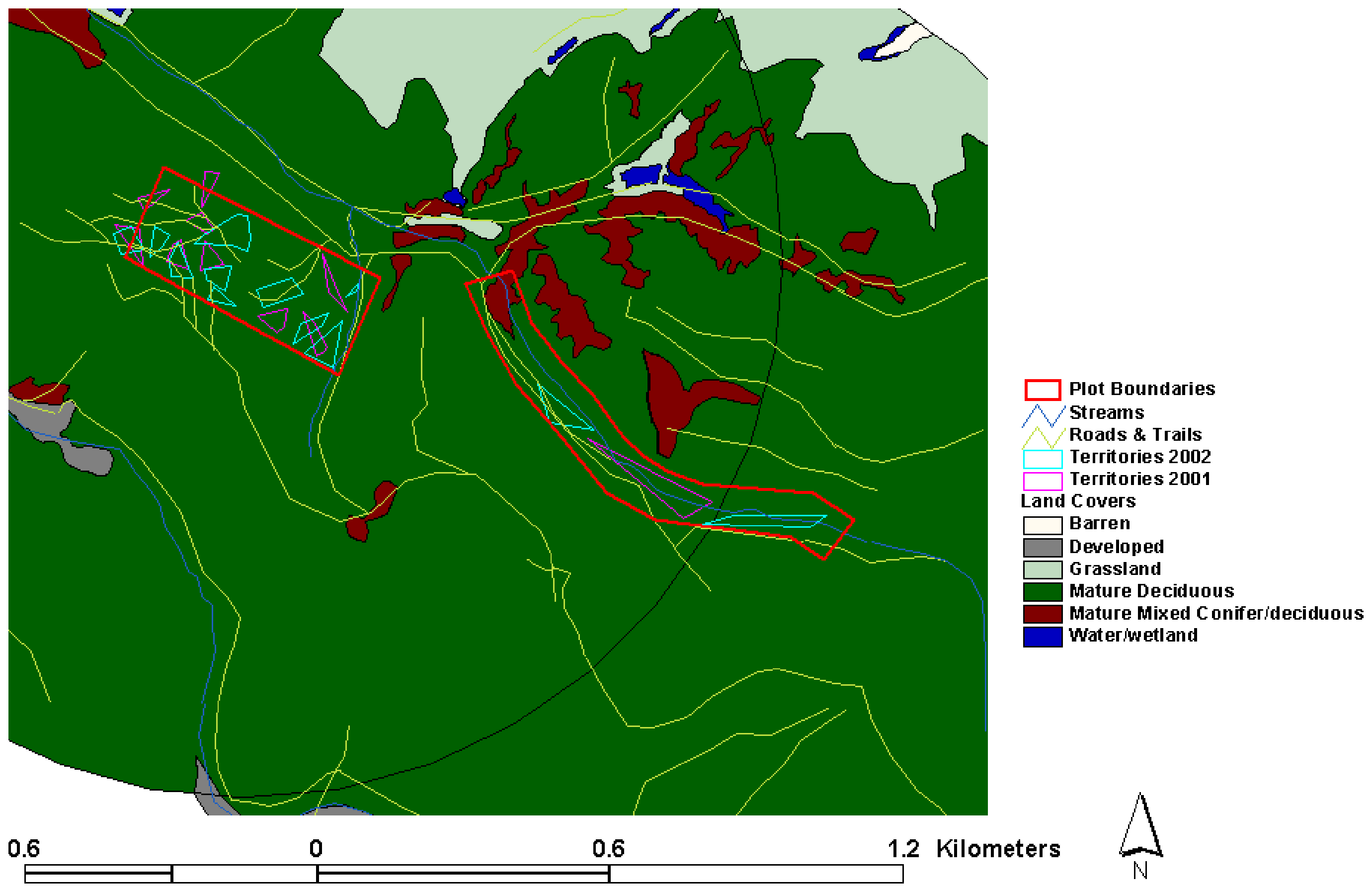

Figure 14. Intact forest plots and Cerulean Warbler territories in 2001 and 2002 at the Hobet Mine.

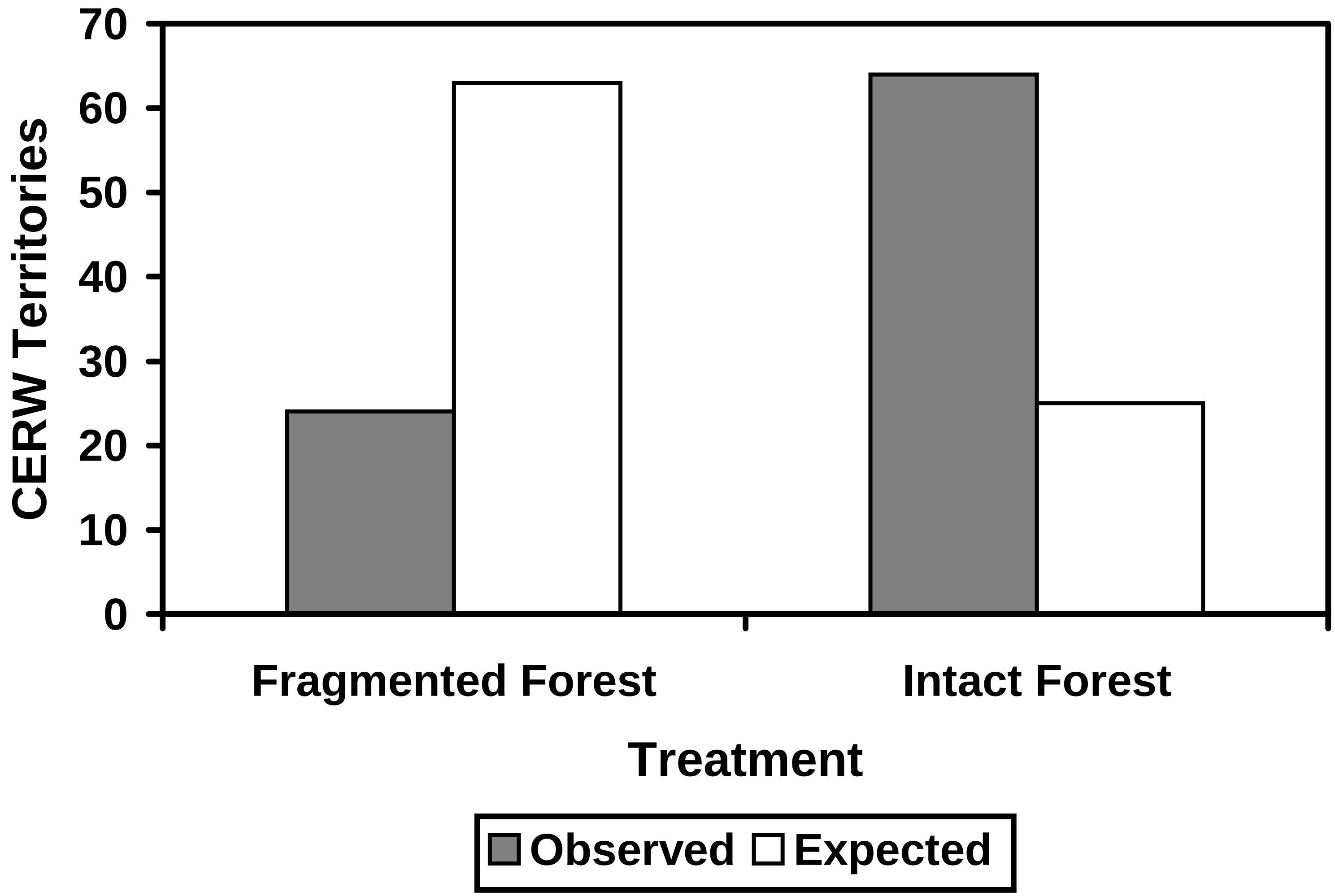

Figure 15. Observed and expected number of Cerulean Warbler (CERW) territories per 10 ha in forests fragmented by MTMVF mining and in intact forests in southern West Virginia 2000-2001. Expected number of territories are based on the amount of available habitat.

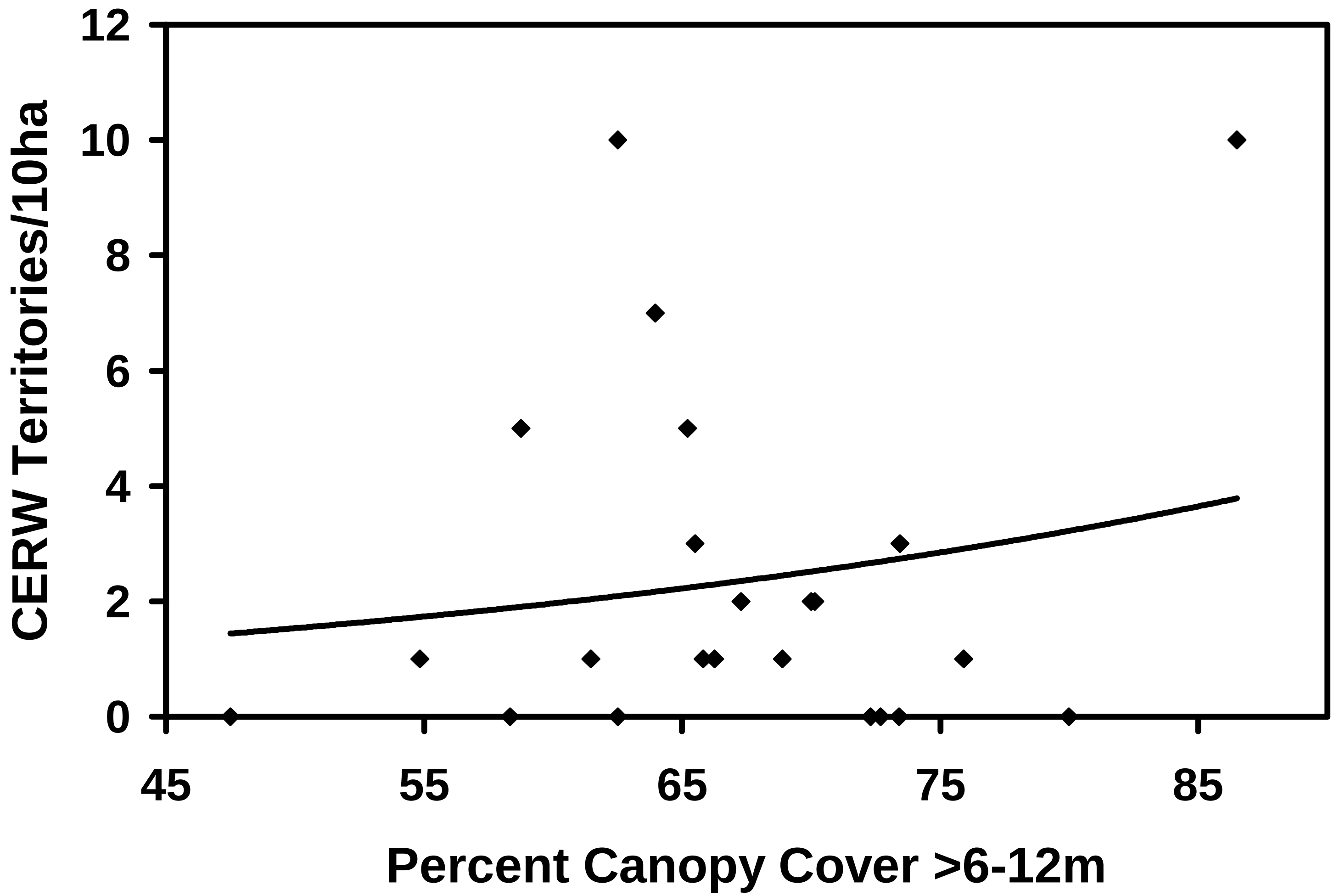

Figure 16. Relationship between Cerulean Warbler (CERW) territory density and percent canopy cover >6-12m.

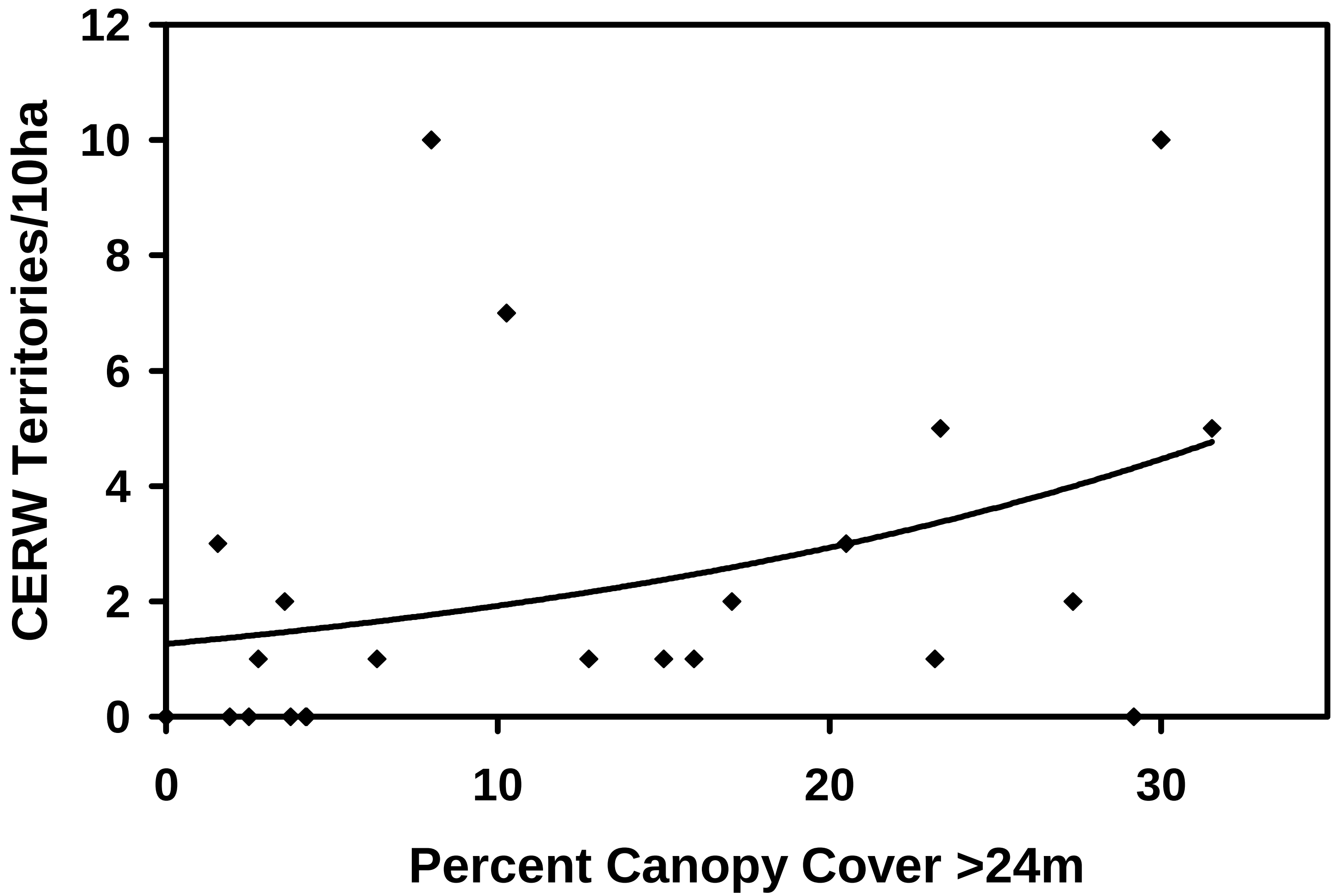

Figure 17. Relationship between Cerulean Warbler (CERW) territory density and percent canopy cover >24m.

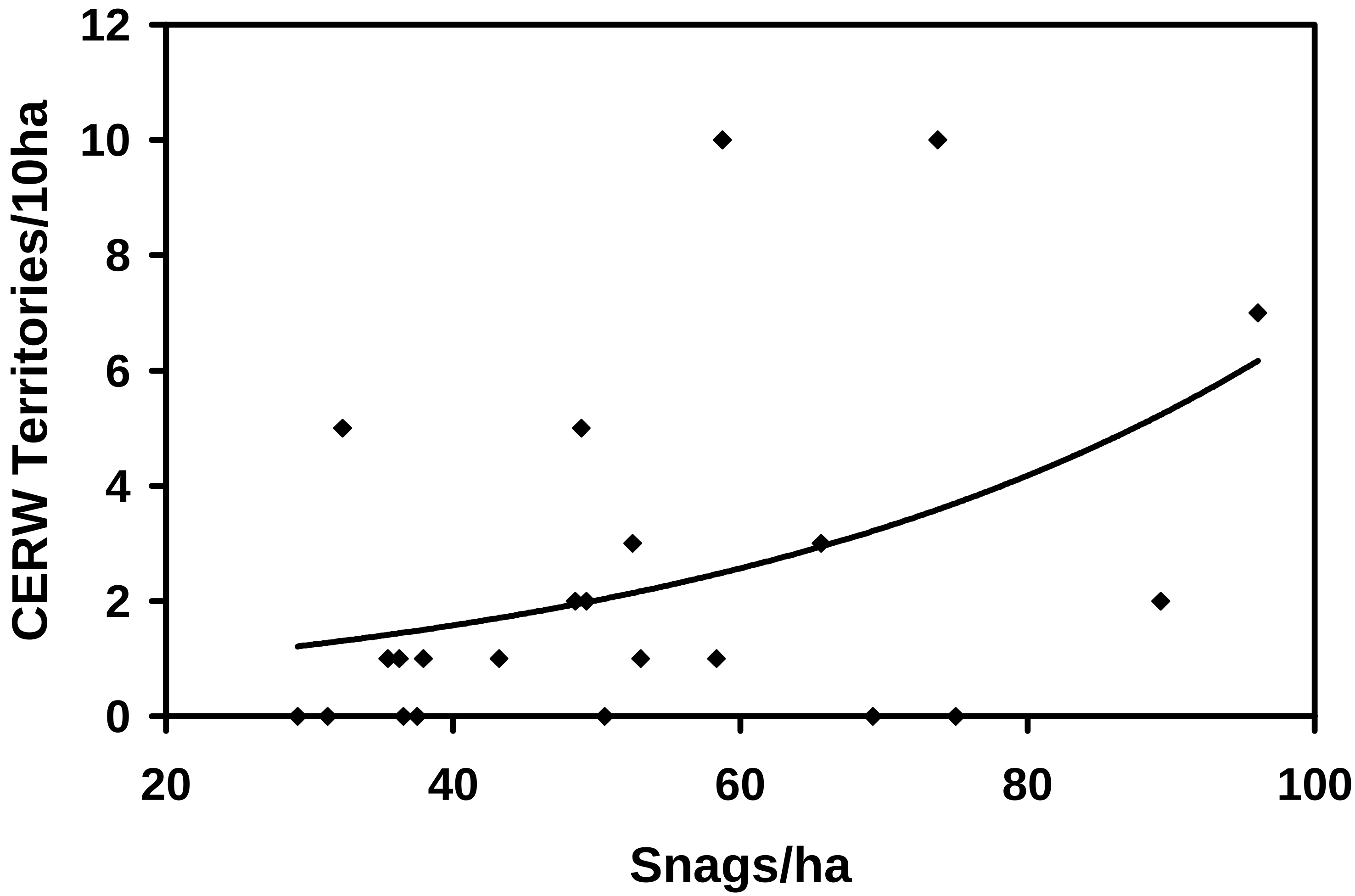

Figure 18. Relationship between Cerulean Warbler (CERW) territory density and snag density (standing dead trees >8 cm dbh).

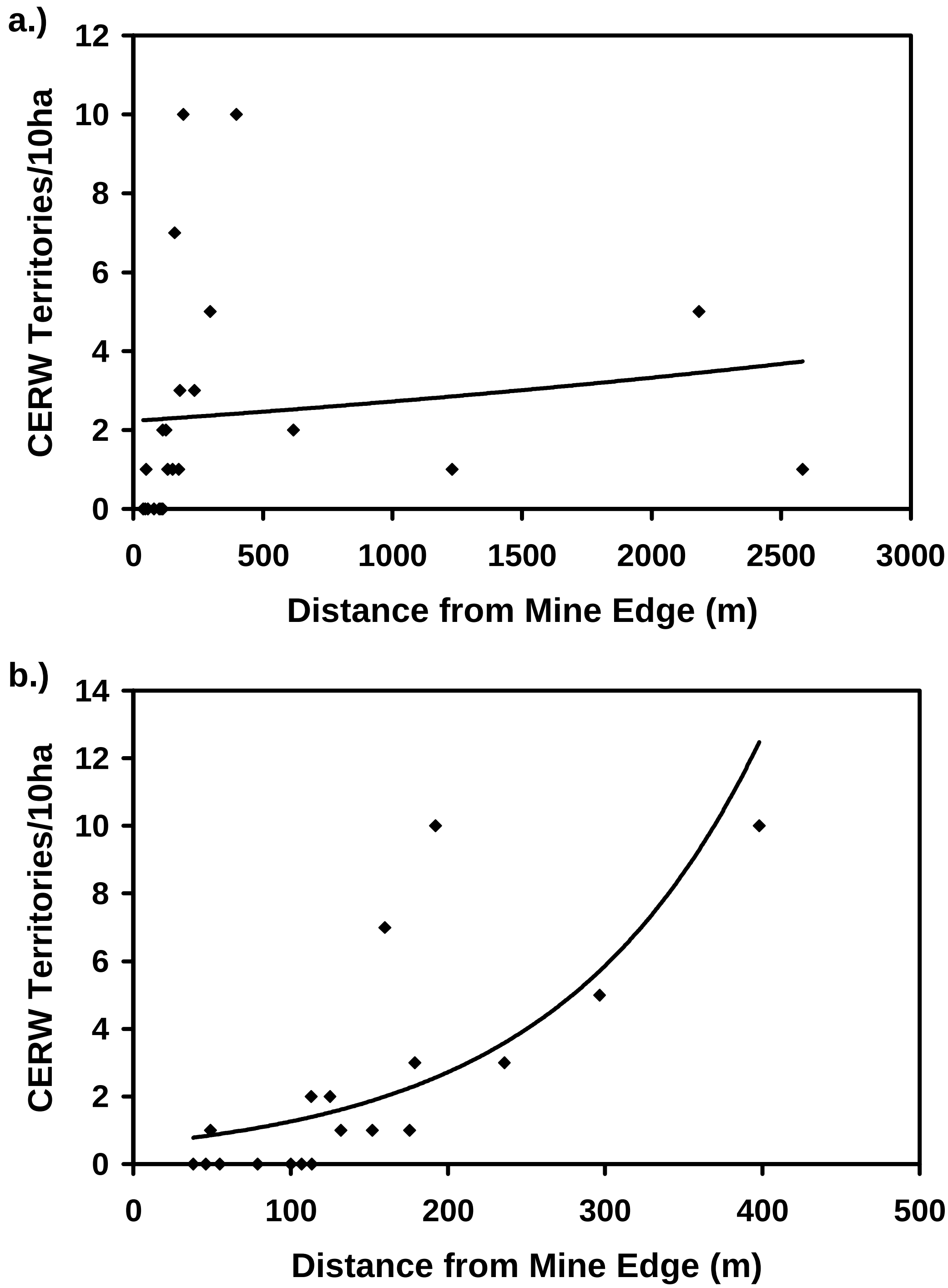

Figure 19. Relationship between Cerulean Warbler (CERW) territory density and distance from mine edge at a) all distances, and b) distances <500m.

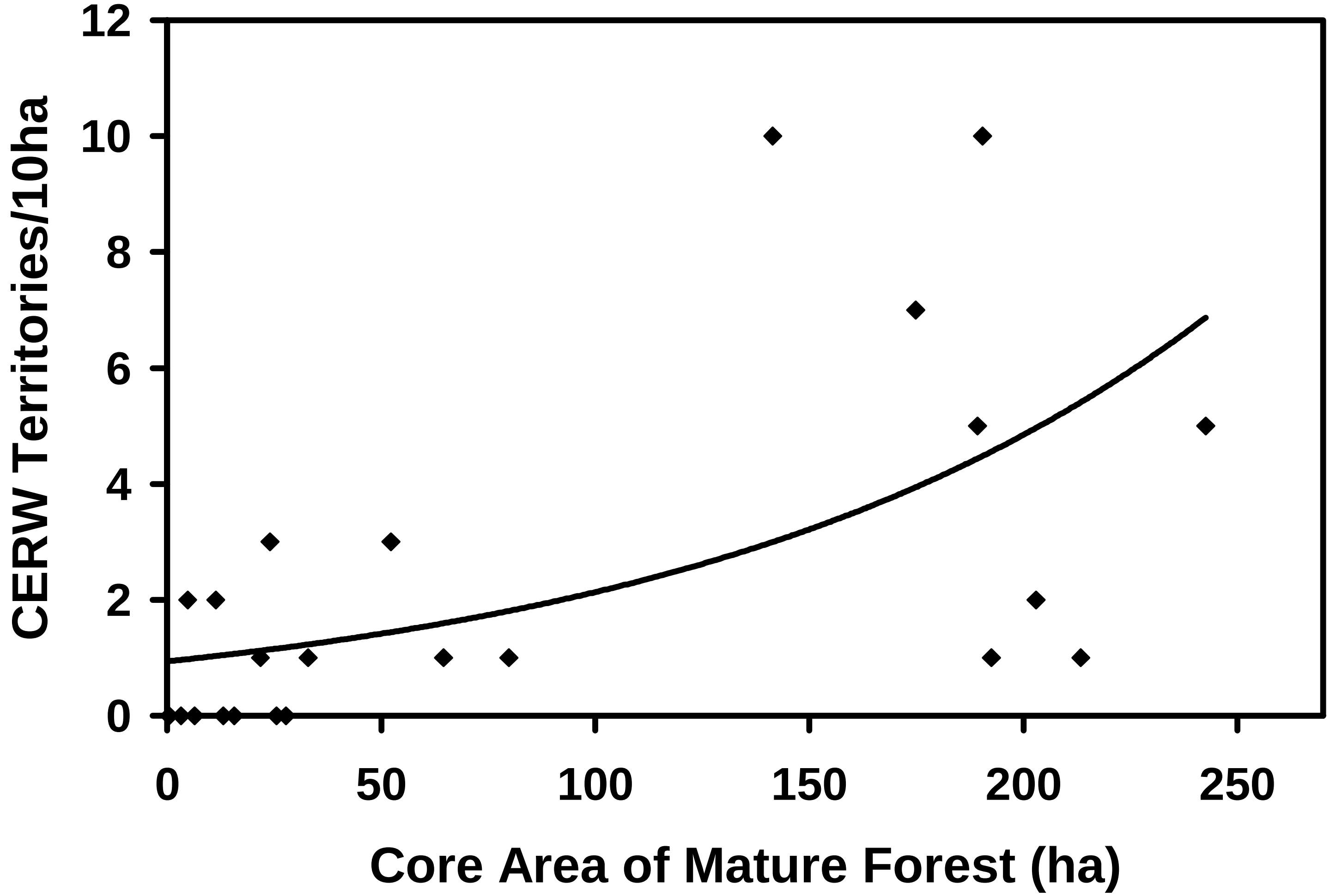

Figure 20. Relationship between Cerulean Warbler (CERW) territory density and core area of forest (forest >100m from an edge).

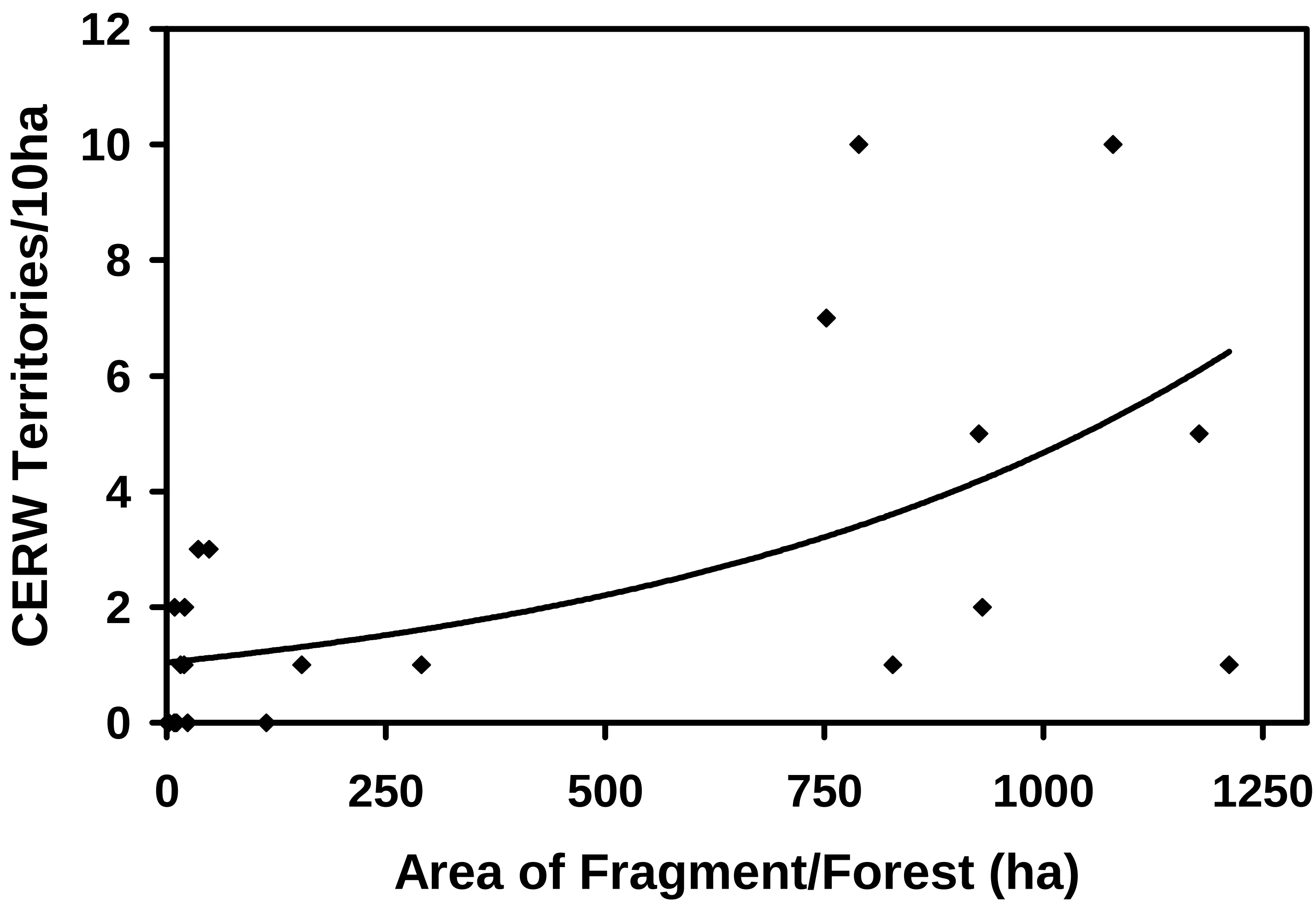

Figure 21. Relationship between Cerulean Warbler (CERW) territory density and area of forest fragment or area of continuous forest within 2-km of plot centers.

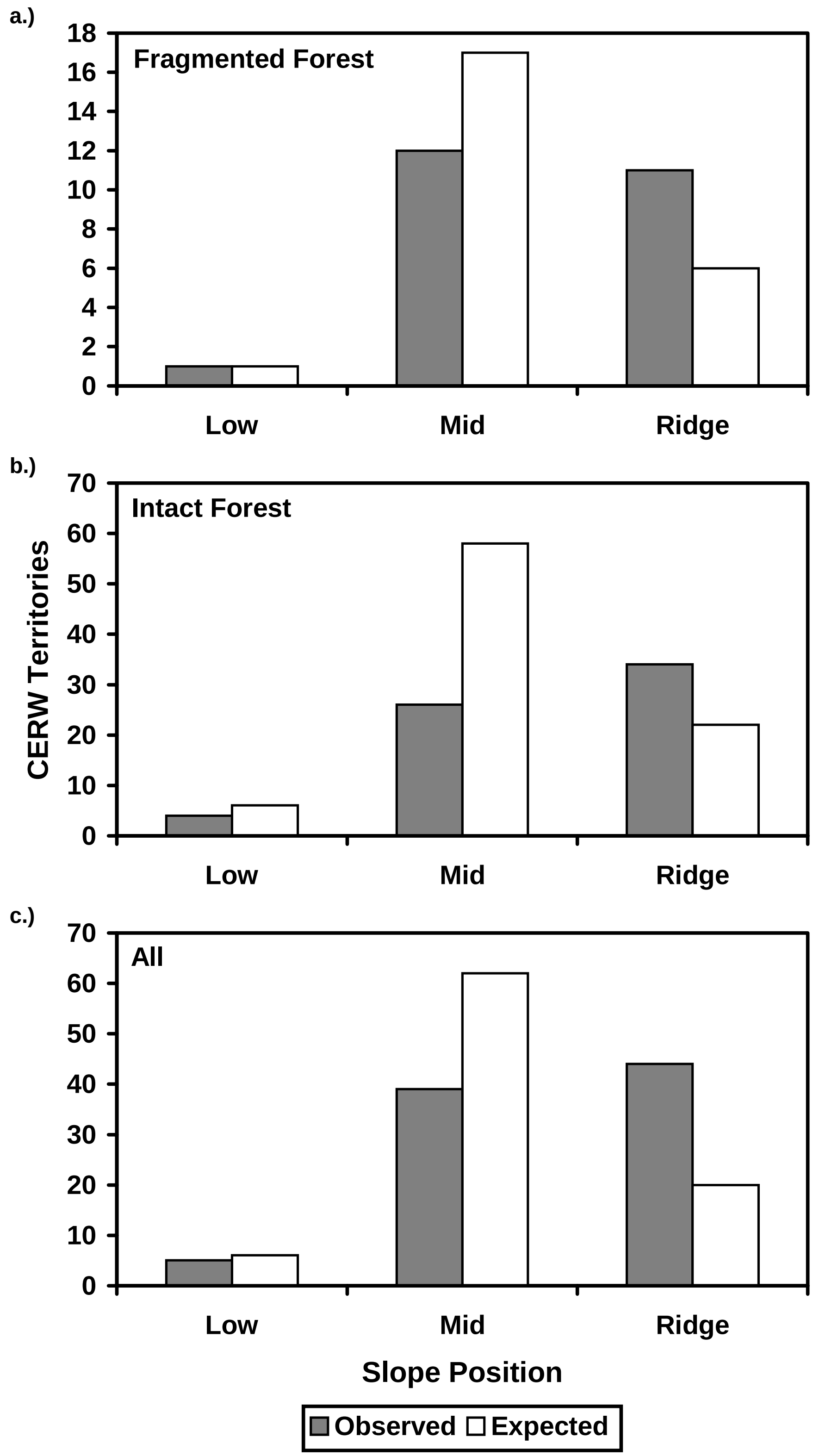

Figure 22. Observed and expected number of Cerulean Warbler (CERW) territories relative to slope position in a) fragmented, b) intact, and c) both fragmented and intact forests combined in southern West Virginia. Expected territories are based on the amount of available habitat.

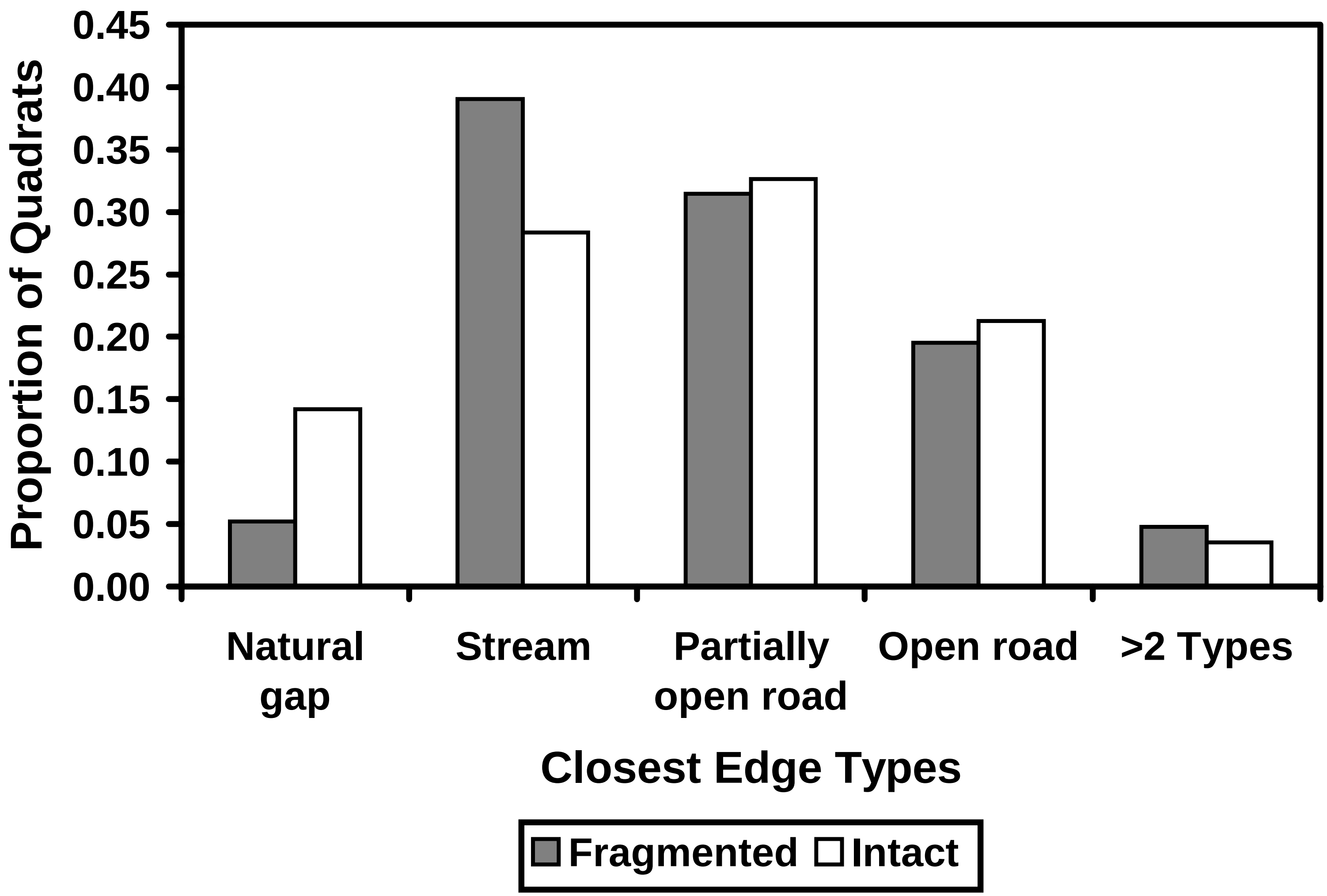

Figure 23. Distribution of closest edge types in forests fragmented by MTMVF mining and intact forests in southern West Virginia.

Appendix 1. Contrasts and weights used to calculate the contrast-weighted edge density[a].

Ecotone Contrasts	Weight
Mature Deciduous - Mature Mixed Conifer/Deciduous	0.00
Mature Deciduous - Grassland	1.00
Mature Deciduous - Barren	1.00
Mature Deciduous - Shrub/pole	0.50
Mature Deciduous - Water/wetland	0.25
Mature Deciduous - Developed	1.00
Mature Mixed Conifer/Deciduous - Grassland	1.00
Mature Mixed Conifer/Deciduous - Barren	1.00
Mature Mixed Conifer/Deciduous - Shrub/pole	0.50
Mature Mixed Conifer/Deciduous - Water/wetland	0.25
Mature Mixed Conifer/Deciduous - Developed	1.00
Grassland - Barren	0.25
Grassland - Shrub/pole	0.50
Grassland - Water/wetland	0.25
Grassland - Developed	0.25
Barren -Shrub/pole	0.75
Barren - Water/wetland	0.25
Barren - Developed	0.00
Shrub/pole - Water/wetland	0.25
Shrub/pole - Developed	0.75
Water/wetland - Developed	0.25

[a] Edge is the sum of the perimeters of all habitat patches. Edge density (m/ha) is amount of edge relative to the landscape area. Contrast-weighted edge density allows edges of different types to contribute varying amounts to this metric. Weights represent the magnitude of contrast between adjacent habitat patches. Ecotones were given weights relative to differences in vegetation structure.

Appendix 2. Means and standard errors of microhabitat variables at territory centers in fragmented (n=23) and intact forest (n=62) and at non-use subplots (fragmented=272, intact=140)

	Territories				Non-use Subplots				Combined			
	Fragmented		Intact		Fragmented		Intact		Territories		Non-use	
Variables	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Aspect Code	1.0	0.1	1.5	0.1	1.0	0.0	1.1	0.1	1.4	0.1	1.0	0.0
Slope (%)	38.4	4.9	47.7	2.1	38.6	1.3	44.7	2.1	45.0	2.1	40.7	1.1
Distance to closest edge (m)	22.6	6.3	33.2	4.1	38.4	2.5	29.5	2.8	30.2	3.4	35.4	1.9
Average canopy height (m)	18.5	1.0	17.6	0.4	19.8	0.3	18.5	0.4	17.9	0.4	19.4	0.2
Percent Canopy Cover:												
>0.5- 3 m	34.8	5.1	34.8	2.9	45.1	1.5	37.3	1.8	34.8	2.5	42.4	1.2
>3-6 m	59.3	6.0	53.6	3.1	64.6	1.4	57.6	2.1	54.6	2.8	62.2	1.2
>6-12 m	66.5	4.4	68.6	2.6	68.7	1.3	64.5	1.7	67.5	2.2	67.3	1.0
>12-18 m	69.8	5.1	62.7	2.7	61.5	1.5	61.3	1.8	64.4	2.4	61.4	1.1
>18-24 m	46.1	6.5	45.2	3.2	36.2	1.8	46.2	2.0	45.7	2.9	39.6	1.4
>24 m	8.7	3.2	19.0	3.0	11.3	1.3	17.9	1.8	16.8	2.4	13.5	1.1
Stem Densities (no./ha):												
<2.5 cm	9462.0	2725.9	6633.2	615.7	6204.5	451.6	6797.9	508.2	7389.7	863.9	6407.1	343.9
2.5-8 cm	809.8	97.8	698.8	60.8	852.0	37.1	859.0	57.7	722.1	51.6	854.4	31.3
>8-23 cm	3315.2	241.6	3438.5	177.6	403.4	13.6	343.1	13.5	338.5	14.4	382.8	10.1
>23-38 cm	1065.2	118.9	954.9	93.3	96.4	3.7	97.7	4.7	101.5	7.5	96.9	2.9
>38 cm	413.0	78.0	532.8	55.2	41.5	2.1	47.2	3.7	49.7	4.6	43.4	1.9
Snags >8 cm	630.4	84.5	586.1	75.4	48.9	2.8	49.3	4.7	59.7	5.9	49.0	2.4

Appendix 3. Means and standard errors of microhabitat and landscape variables in fragmented forests (n=15) and intact forest (n=8) in southern West Virginia.

	Fragmented Forest		Intact Forest	
Variables	Mean	SE	Mean	SE
Microhabitat				
Aspect Code	0.9	0.1	1.2	1.3
Slope (%)	41.5	2.8	45.6	5.1
Distance to closest edge (m)	35.3	4.3	28.8	4.8
Average canopy height (m)	19.6	0.6	18.1	2.2
Percent Canopy Cover:				
>0.5-3m	41.4	3.5	35.5	6.1
>3-6m	64.5	3.0	56.9	6.8
>6-12m	67.7	2.1	66.0	6.8
>12-18m	63.4	2.9	61.2	6.1
>18-24m	40.0	4.8	46.7	5.6
>24m	9.8	2.7	18.5	6.7
Stem Densities (no./ha):				
<2.5cm	5821.3	517.2	7191.3	1220.5
2.5-8cm	877.0	87.5	796.2	118.3
>8-23cm	392.9	29.4	350.2	53.9
>23-38cm	96.4	6.4	95.9	11.3
>38cm	41.6	4.8	48.0	6.7
Snags (>8cm)	51.7	4.5	54.1	8.5
Landscape				
Cover (ha):				
Barren	5.5	1.0	3.5	2.1
Grassland	146.0	16.1	31.5	32.8
Shrub/pole	47.7	10.1	12.0	5.6
Water/wetlands	2.0	0.3	0.4	1.4
Mature deciduous forest	91.1	9.6	247.0	38.9
Mature mixed conifer/deciduous forest	14.0	2.7	13.3	4.3
Developed	6.5	3.1	5.0	2.4
Fragmentation Indices:				
Contrast-weighted edge density	43.0	3.1	24.8	4.6
Core area mature forest	25.6	6.0	193.4	33.8
Distance to mine edge (m)	113.3	14.5	957.2	295.2
Area of fragment/intact forest	51.0	20.4	961.7	176.7

Selenium Workshop,
April 13th, 2004
Charleston, WV.
Summary

Selenium Workshop
April 13th, 2004 Charleston, WV
Summary

A brief summary of the selenium workshop held in Charleston, WV, on April 13th. The workshop, sponsored by the West Virginia District of the U. S. Geological Survey Water Resources Discipline, was attended by 74 representatives of state and federal agencies and academia. A list of attendees, their affiliation, and email addresses are supplied as an attachment to this summary.

The session's first presentation was from John Wirts, Environmental Resources Manager with West Virginia Department of Environmental Protection's Watershed assessment Program. Water-quality studies conducted as part of the Mountaintop Mining/Valley Fill EIS found selenium concentrations in streams to exceed WVDEP's limit of 5 µg/L. These findings resulted in the listing of 9 streams on WVDEP's 2002 Section 303(d) list of impaired streams; 4 streams in the Coal River basin, 4 in the Guyandotte River Basin and 1 in the Gauley River Basin. John described results of WVDEP studies conducted as part of routine stream condition monitoring, development of TMDLs, and one study assessing potential impacts of the "King Coal" highway to be built in southern W. Va. Of the five stream basins sampled as part of the WVDEP's Watershed Assessment Program and TMDL development, the Coal, Elk, North Branch of the Potomac, Lower Kanawha, and Tygart River Basins, selenium was found primarily in the Coal River Basin, 121 of 126 detections, and largely in association with surface mining operations. Analysis of "King Coal" highway samples found that exceedance of Se criteria was not related to storm flow events, but associated with base flow conditions.

Cindy Tibbott, a biologist with U. S. Fish and Wildlife Service's Pennsylvania Field Office, presented results of the analysis of fish tissues collected downstream from mountaintop mining areas. Creek chub (*Semotilus atromaculatus*) and blacknose dace (*Rhinichthys atratulus*) were primarily targeted for collection, bluegill (*Lepomis macrochirus*) were collected from one sediment pond. Selenium was present in all sampled tissue. At several locations tissue concentrations exceeded 4 ppm, a level that can result in reproductive failure and juvenile mortality. Some tissues approached a 7 ppm Se concentration that can result in reproductive failure in birds consuming these tissues. It is apparent that Se is entering food webs in the areas sampled, a situation that deserves further attention.

USEPA comments on the regulatory environment were presented by Dan Sweeney, NPDES coordinator for Region 3, Philadelphia.

Roger Calhoun, Director of the Office of Surface Mining and Reclamation's Charleston Field Office, provided OSM's perspective on selenium in the mountaintop mining/valley fill region. Roger described OSM's roles providing oversight of state-run regulatory programs, providing technical support and research assistance, and acting in a regulatory capacity in some states.

Preliminary results of selenium analyses of care samples from the central Appalachian coal basin were provided by Blaine Cecil of USGS Geologic Division's Eastern Energy Resource Team. Blaine has been working with colleagues from the West Virginia Geologic and Economic Survey (WVGES) and West Virginia University (WVU) to determine the selenium content of coal-bearing strata. The selenium content of coal has been thoroughly examined in West Virginia and this data is available at WVGES's website (http://www.wvgs.wvnet.edu/www/datastat/te/index.htm). From the analysis of coal, it was apparent that the coal beds targeted by mountaintop mining are enriched in Se compared to coal beds both lower and higher in the geologic sequence. Analysis of coal-bearing strata has been completed for only one core to date; therefore any conclusions based upon this data are highly preliminary in nature. The results of analysis of the first core indicate that the rock, as well as the coal, is enriched in Se relative to both older and younger strata. Main points of Blaine's talk were that regional, three-dimensional patterns in coal-bearing strata cannot be determined on the basis of one core, but the one core analyzed thus far (USGS 9) indicates that Se concentrations in rock follows trends in coal , and that Se concentrations for both rock and coal were relatively higher in the interval targeted by mountaintop mining.

Theresa Presser, research chemist working in Se biogeochemistry with the USGS's National Research Program in Menlo Park Ca., presented a short course in "Environmental selenium 101" supported by case studies. Selenium is an essential micronutrient in bacteria and animals. Beneficial effects in humans stem mainly from Se's role as an antioxidant. However, Se is the most toxic of all biologically essential elements in mammals. Fish and birds are the most sensitive taxa to aquatic Se contamination. Although extreme Se contamination causes death in adults, the responses of greatest concern are: impairment of reproductive success (failure of eggs to hatch); and teratogenesis (monstrosities in juveniles— lethal or sub lethal deformities). Selenium is passed from parents to their offspring in eggs.

During critical stages of development and growth, toxic effects occur via biochemical pathways unable to distinguish Se from sulfur, thus substituting Se-containing amino acids, e.g. seleno-methionine or seleno-cysteine, in structural and functional proteins. Both fish and bird embryos may be deformed by selenium. Teratogenesis, however, is not the most sensitive toxic endpoint. Selenium toxic endpoints in increasing order of sensitivity are: adult mortality, juvenile mortality, teratogenesis, mass wasting in adults, embryo mortality, reduced juvenile growth, and immunosuppression

Studies show that predators are more at risk from Se contamination than their prey, making it difficult to use traditional methods to predict risk from environmental concentrations alone. Biological levels of Se that transfer through food webs ultimately determine the ecological effects of Se. For example, aquatic organisms that are the food of wildlife strongly bioaccumulate Se, perhaps to thousands of times the waterborne concentration, but are unaffected by tissue residues. However, those levels of tissue residue are high enough to cause reproductive failure when consumed by fish and aquatic birds. Thus bioaccumulation in aquatic food chains and dietary transfer to eggs causes otherwise harmless concentrations of waterborne Se to become toxic.

Traditional toxicity tests are problematic because they determine toxicity only via direct water-borne exposures. In the environment direct transfer of Se from solution to animals such as fish and bivalves is a small proportion of exposures. Bioaccumulation and uptake via food is the most important route of Se transfer to upper trophic level species. A predator's choice of food, which varies widely among species, results in some trophic pathways being more efficient accumulators of Se than others. Thus, bioaccumulation models must link food sources to predator animals to predict biotic effects. And food webs may be as an important variable as input loads.
Pathway bioaccumulation models consider:

- biotransformation to different speciation regimes
- bioaccumulation via the lower trophic food web
- uptake of food by predator species (trophic transfer

Analysis of one of the above sets of processes, in isolation, is inadequate to characterize Se effects. If correlations made among factors or processes skip links, then serious uncertainties will result.

- Alternative approaches for developing selenium (Se) criteria are needed.
- Traditional methodologies based on water-only exposure of Se for development of Se criteria do not apply to elements that bioaccumulate.
- Failure to consider the full sequence of interacting processes of food webs that result in Se toxicity is a major cause of controversy and confusion about Se effects on the environment.
- Linked multi-media and watershed mass-balance approaches would include all considerations that cause systems to respond differently to Se contamination.
-

Environmental effects of selenium contamination can include:

- Fish mortality and deformities in wildlife
- Posting of human health advisories for consumption of contaminated fish and wild birds
- Termination of grazing

Therefore, accurate forecasting of the environmental fate of selenium is needed. Past studies show that predators are more at risk from Se contamination than their prey, making it difficult to use traditional methods to predict risk from environmental concentrations alone.

Joseph Skorupa, of the U. S. Fish and Wildlife Service's Division of Environmental Quality, presented a technical review of EPA's draft tissue-based selenium criteria. Joe presented some background information on the need for revised Se criteria. The background was followed by a "preamble" statement expressing points of consensus among EPA, the Fish and Wildlife Service and the National Marine Fisheries Service (the Services).

Skorupa noted that, despite points of consensus, there are some disagreements between EPA and the Services. These disagreements trace back to differences in conceptual foundations based in the Endangered Species Act (ESA) and the Clean Water Act (CWA) and the acceptability of a 20 percent effect concentration (EC20). The Services' perspective is based in the ESA, which considers every individual of a species important, both legally and biologically, in order to maximize recovery, and seeks to determine zero toxicity thresholds at the level of individuals. In other words, an EC20 represents an unacceptable loss of biological capital, especially for vulnerable species. EPA's perspective draws upon CWA, with a population level focus allowing for "tolerable" levels of toxic effects upon populations where an EC20is an acceptable risk. These conceptual differences have lead to complications for CWA criteria and disagreement on toxicity threshold points.

These conceptual differences between the Services and EPA are exacerbated by technical, scientific flaws in the draft tissue-based Se criteria. These flaws include but are not limited to:

- Lemly's 7.9 μg/L Se/g, the controlling basis for the draft tissue-based criterion , is at best an LC50 and at worst a tissue concentration that exceeds the LC50 by 36%
- The crucial regression equation relating whole-body Se to ovary Se is erroneously reported
- Assessments of risk to wildlife were based on Opreska *et al*., (1995) instead of the much revised and updated Sample *et al*. (1996) which makes a big difference
- Grossly incorrect wet-weight-to-dry-weight conversions invalidate the wildlife analysis based on Opreska *et al*. (1995)
- Available data for wildlife taxa more sensitive than fish-eating birds to Se were totally ignored, both from Opreska *et al*. (1995) and other sources
- Data from the USGS NAWQA National Database were misused, i.e., invertebrate and fish liver data were reported and plotted as fish whole-body data

Joe followed a discussion of the specific flaws with three key points. First, Skorupa and his co-authors (Theresa Presser, USGS-WRD National Research Program, Menlo Park CA; Steve Hamilton, USGS-BRD, Columbia Environmental Research Center, Yankton, SD; and Dennis Lemly, U. S. Forest Service's Coldwater Fisheries Research Unit, Blacksburg, VA) believe that there are multiple substantive technical errors in the "7.9" tissue-based draft proposal. Second, EPA and FWS already agree that the "7.9" proposal will not protect aquatic-dependent wildlife. And third, the Fish and Wildlife Service believes that an aquatic life criterion of <5.8 μg Se/L is warranted; EPA is undecided and would like to review and evaluate the matter further. Joe closed with a concluding message: "It is premature to use the "7.9" draft proposal for regulatory or other decision-making purposes. The final criterion may, or may not, differ from the current draft proposal; and in any case, won't apply to wildlife."

Dr. Paul Ziemkiewicz of the West Virginia Water Resources Research Institute described selenium research being conducted at the National Mine Land Reclamation Center at West Virginia University. There are four current areas of Se research underway: evaluate available overburden cores and other geologic material samples to identify sources and forms of Se in the strata, analyze overburden cores from mining areas within Se Impacted watersheds of southern WV, analyze for total Se, and identify Se-rich rock units. Evaluation of the geo chemical mechanisms of Se mobilization will be accomplished through the sequential extraction of Se-rich rock units to discriminate sources of Se, i.e. sulfides, oxides, organic matter, or carbonates. Additionally weathering tests will be evaluated to assess Se mobility. Programs to identify and develop treatment methods to reduce Se mobility and remediate Se contaminated waters in the laboratory will investigate Se speciation within mine spoils and at mine discharges, evaluate selective handling options, and examine *in situ* and *ex situ* treatment. Additional work items are to Future programs Identify and evaluate passive treatment options for existing sources and streams and initiate laboratory bench column and humidity cell experiments for weathering and *in situ* treatment options

Dr. Dorothy Vesper, Professor of Geology at West Virginia University, presented findings of her Se research, the focus of which has been developing analytical methods for speciating Se and applying these methods to the field. The analytical method used by Dr. Vesper is Hydride-Generation Atomic Absorption Spectroscopy (HG-AAS). Although this method measures only Selenite (+IV), concentrations of Selenate (+VI) can be determined through analysis of a sample that has been digested, thereby reducing selenate to selenite, the difference between the digested and undigested samples being selenate. The applicability of this method to environmental samples was tested by analyzing samples collected below valley fills in the upper Mud River Basin. This basin was selected because Se had previously been found in this basin. Preliminary conclusions indicate that:

- Nearly all (>90%) of the Se in Mud River samples is Se(VI)
- The sample from the spoil pond is less oxidized (~70% is SeVI)
- Samples with concentrations near the MDL are very difficult to speciate

There are several outstanding research questions for streams and watersheds, chief among these are:

- Developing a better understanding of speciation on watershed scale
- Determining the partitioning between organic-bound or elemental species
- Importance of particulate/sediment in Se transport
- Accumulation in sediments
- Temporal variability –in spoils, water

There are additional unresolved questions pertaining to relations among solid and aqueous phases of Se, including determining the relationship between total and leachable Se, and how Se is in bound in geologic materials.

Doug Chambers, Biologist and District Water-Quality Specialist with the USGS-WRD's West Virginia District office, concluded the workshop with a presentation of a proposal to study Se fate and transport in watersheds containing valley fills. The objectives of this study will be to:

- Determine the fate and transport of selenium as it moves from valley fill to sediment pond to stream.
- Examine processes and factors thought to be in important controlling selenium transport and biological uptake.
- Identify important pools of selenium and how it is partitioned among these pools.
- Examine probable pathways of bioaccumulation.

The USGS proposes to characterize changes in forms and concentrations of selenium in stream water, sediments, and biological matrices as it moves from fills through sediment control structures to streams in the coalfields of southern West Virginia. By tracking transformations of selenium and changes in Se fractionation among sampled media while monitoring attendant environmental conditions, the USGS will be able to identify key steps and controls in the transport and cycling of Se in streams in the region.

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USGS 2001
Flooding Study

U.S. Department of the Interior
U.S. Geological Survey

Comparison of Peak Discharges among Sites with and without Valley Fills for the July 8–9, 2001, Flood in the Headwaters of Clear Fork, Coal River Basin, Mountaintop Coal-Mining Region, Southern West Virginia

By JEFFREY B. WILEY and FREDDIE D. BROGAN

Open-File Report 03-133

In cooperation with the
OFFICE OF SURFACE MINING RECLAMATION AND ENFORCEMENT

Charleston, West Virginia
2003

U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY
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CONVERSION FACTORS AND VERTICAL DATUM

CONVERSION FACTORS

Multiply	By	To Obtain
acre	4,047	square meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
square mile (mi^2)	2.590	square kilometer

VERTICAL DATUM

Vertical Datum: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NDVD 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.

Comparison of Peak Discharges among Sites with and without Valley Fills for the July 8–9, 2001, Flood in the Headwaters of Clear Fork, Coal River Basin, Mountaintop Coal-Mining Region, Southern West Virginia

By Jeffrey B. Wiley and Freddie D. Brogan

ABSTRACT

The effects of mountaintop-removal mining practices on the peak discharges of streams were investigated in six small drainage basins within a 7-square-mile area in southern West Virginia. Two of the small basins had reclaimed valley fills, one basin had reclaimed and unreclaimed valley fills, and three basins did not have valley fills.

Indirect measurements of peak discharge for the flood of July 8-9, 2001, were made at six sites on streams draining the small basins. The sites without valley fills had peak discharges with 10- to 25-year recurrence intervals, indicating that rainfall intensities and totals varied among the study basins. The flood-recurrence intervals for the three basins with valley fills were determined as though the peak discharges were those from rural streams without the influence of valley fills, and ranged from less than 2 years to more than 100 years.

INTRODUCTION

Increased mechanization of coal mining in West Virginia in recent decades has led to extensive use of mountaintop-removal mining to reach coal seams. Excess overburden from mountaintop removal is placed in adjacent headwater valleys, creating what are known as “valley fills.” Mountaintop mining and valley filling in the coal-mining region of southern West Virginia have changed forested landscapes with layered sedimentary rocks into grass-covered landscapes underlain by poorly sorted rock fragments. The U.S. Geological Survey (USGS), in cooperation with the Office of Surface Mining Reclamation and Enforcement, investigated the effects of valley fills on the peak discharges for the flood of July 8-9, 2001, in the headwaters of Clear Fork in the Coal River Basin. The study area included six sites on streams draining small basins (drainage areas ranging from 0.189 to 1.17 mi^2) within an area of about 7 mi^2 in the headwaters of Clear Fork of the Coal River in the Appalachian Plateaus Physiographic Province in the southern coalfields of West Virginia. Peak discharges after the flood were determined indirectly at the six sites by surveying high-water marks and cross sections, and applying open-channel-flow equations. Peak discharges were compared among basins with and without valley fills.

This study resulted from investigations used to prepare the Mountaintop Mining/Valley Fill Environmental Impact Statement (EIS). The EIS assesses 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 was 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 Service, and the West Virginia Department of Environmental Protection (U.S. Environmental Protection Agency, 2000). Some of the data-collection sites for this study are at or near data-collection sites used in preparation of the EIS.

DESCRIPTION OF STUDY AREA

Six sites on streams draining the small basins in the headwaters of Clear Fork of the Coal River in southern West Virginia were selected for investigation after the flood of July 8–9, 2001 (figs. 1*A*–*C*). The six site identifications are: USGS1, Unnamed Tributary to Lick Run; USGS2, Unnamed Tributary to Clear Fork; MT65C, Unnamed Tributary to Buffalo Fork; MT66, Buffalo Fork; USGS3 (near MT69), Ewing Fork; and MT76, Reeds Branch. The "USGS" prefix indicates that the site was selected by the USGS for this study, and the "MT" prefix indicates that the site had already been used for preparation of the Mountaintop Mining/Valley Fill EIS.

Three sites are on streams that drain basins without a valley fill and without active surface mining (USGS1, USGS2, and USGS3) and three sites are on streams that drain basins with valley fills (MT65C, MT66, and MT76). MT65C is in a basin that has one reclaimed and one unreclaimed valley fill, and there is active surface mining in the basin. A reclaimed valley fill has a configuration and vegetation cover that meets the plan that has been permitted. An unreclaimed valley fill has a configuration that is still under construction or lacks the vegetation cover necessary to meet the requirements of the permit. MT66 has two reclaimed valley fills, and there is active surface mining on the southern ridge of the basin. MT76 has one reclaimed valley fill and there is no active surface mining in the basin. The three sites associated with valley fills are downstream from sediment ponds at the toes of the fills. The surface areas of the individual valley fills, except for the area of the valley fill near MT76, were available from the West Virginia Department of Environmental Protection (2002). The surface area of the valley fill near MT76 was estimated as 0.3 mi^2 (180 acres) from an orthophotograph (the largest valley fill in the study basins). The valley fills range between about 0.02 and 0.3 mi^2 (12 and 180 acres), which is equal to or greater than the average valley-fill surface area of about 0.02 mi^2 (12 acres) in West Virginia (West Virginia Department of Environmental Protection, 2002).

The study area is underlain by consolidated, mostly noncarbonate sedimentary rocks that dip gently to the northwest. The erosion of rocks by streams has formed steep hills with deeply incised valleys that follow a dendritic pattern, and plateaus capped by resistant layers of sandstone and shale (Fenneman, 1938; Fenneman and Johnson, 1946; and U.S. Geological Survey, 1970). 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 flow is greater laterally than vertically and decreases with increasing depth with little flow below 100 ft, except in coal seams, where ground water can flow at depths greater than 200 ft (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 precipitation with a 24-hour intensity of 2.75 in. falls on the average of once every 2 years (U.S. Department of Commerce, 1961).

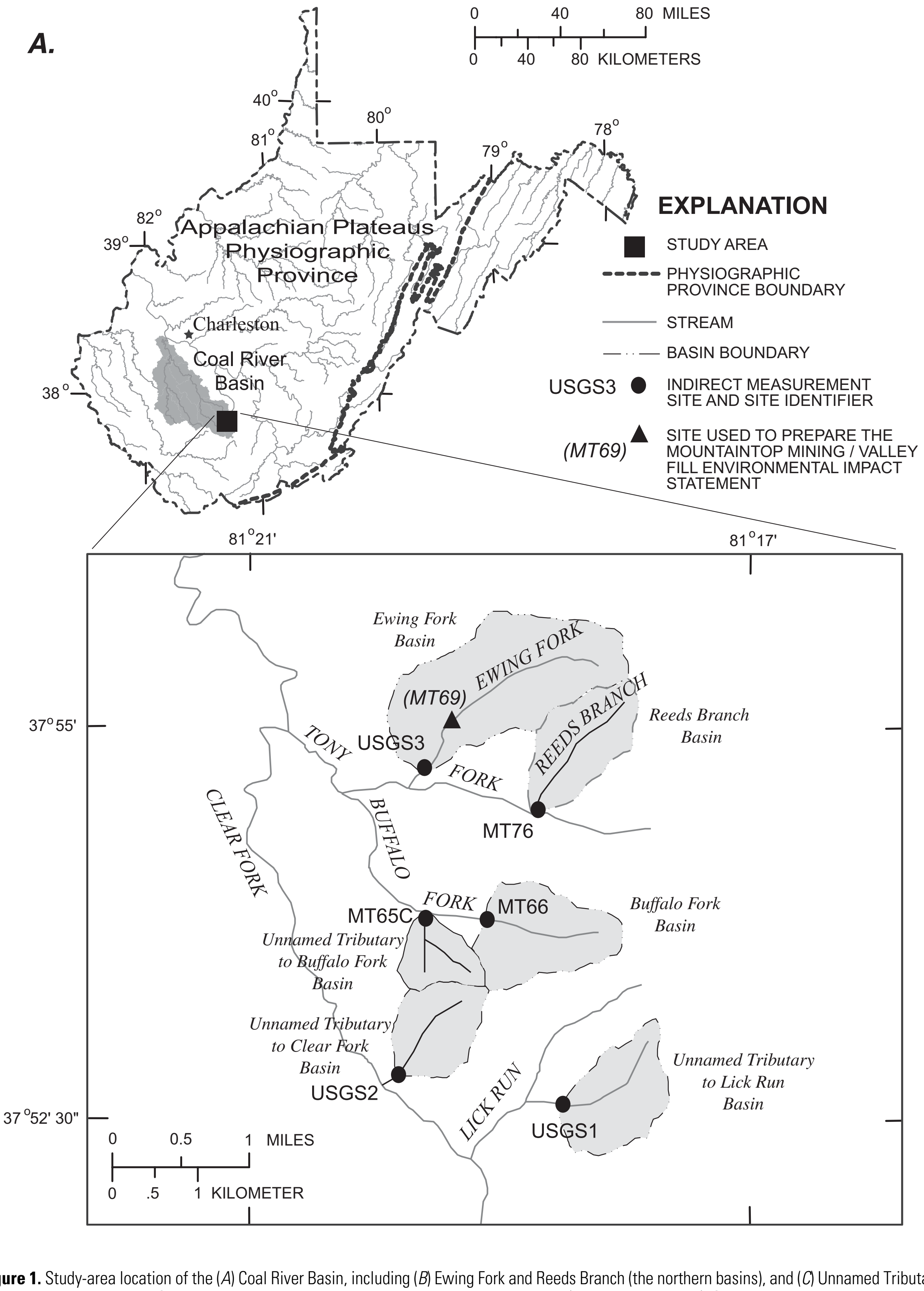
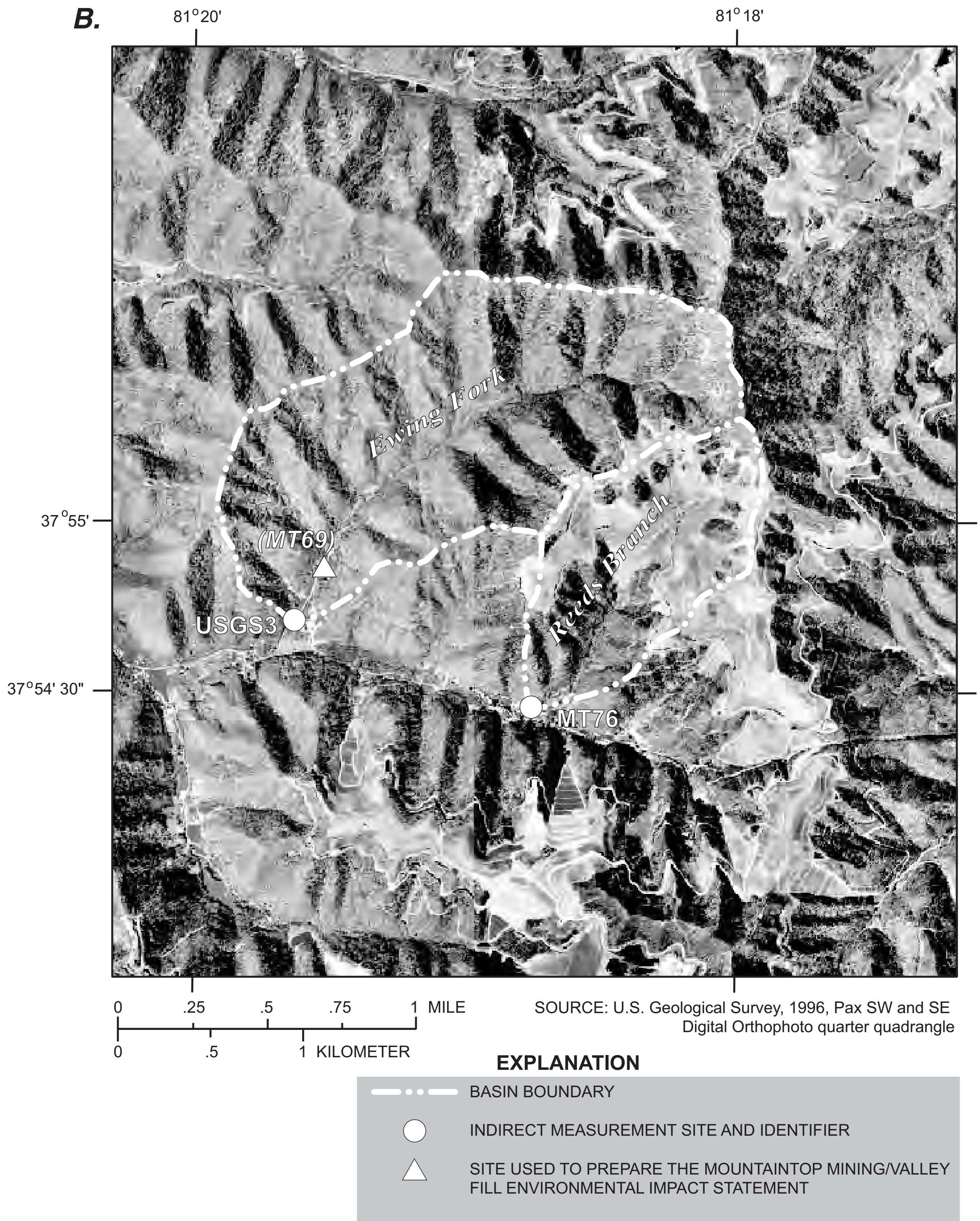


Figure 1. Study-area location of the (*A*) Coal River Basin, including (*B*) Ewing Fork and Reeds Branch (the northern basins), and (*C*) Unnamed Tributary to Lick Run, Unnamed Tributary to Clear Fork, Unnamed Tributary to Buffalo Fork, and Buffalo Fork (the southern basins), Coal River Basin, mountaintop coal-mining region, southern West Virginia.



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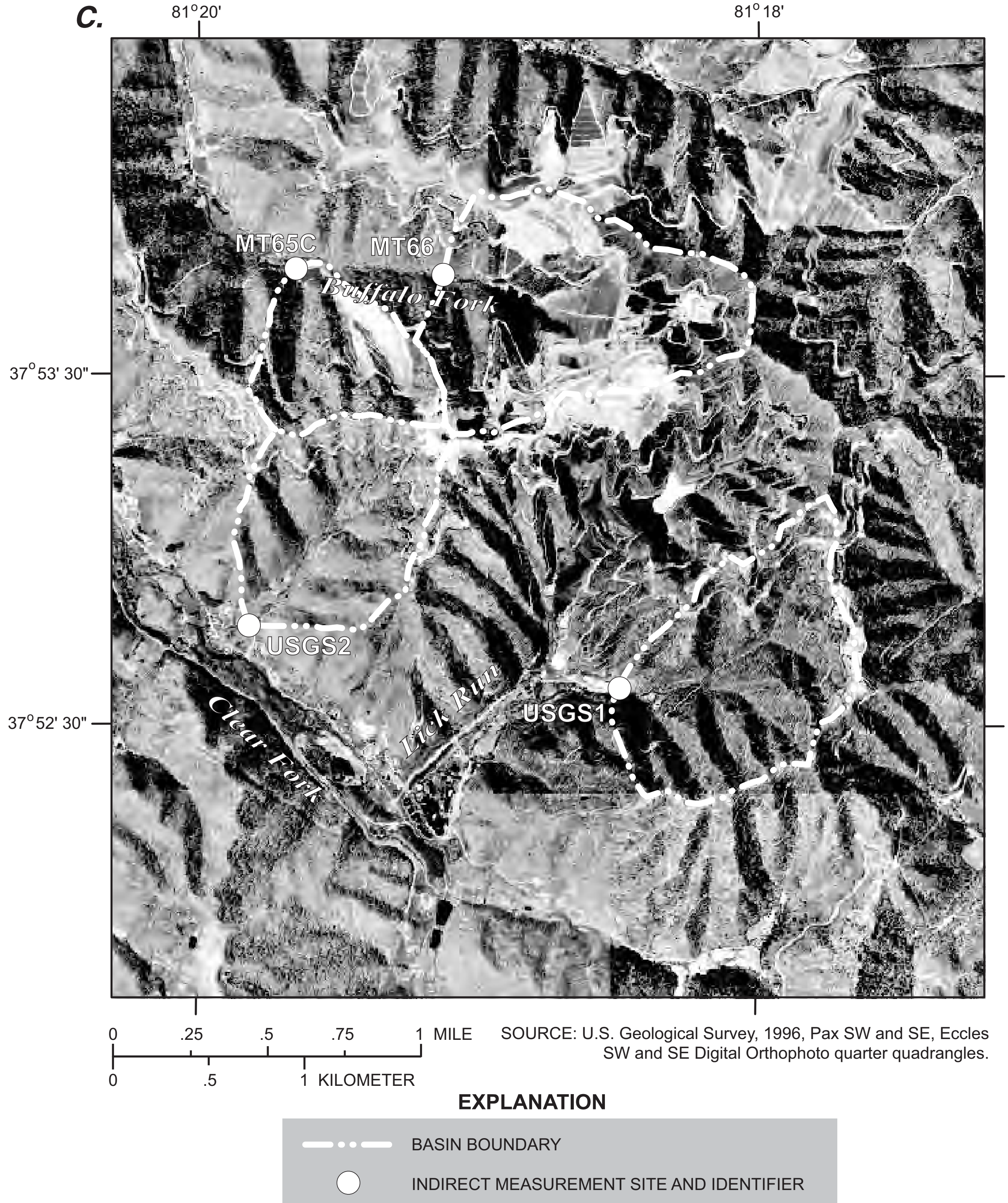

Figure 1. Study-area location of the (*A*) Coal River Basin, including (*B*) Ewing Fork and Reeds Branch (the northern basins), and (*C*) Unnamed Tributary to Lick Run, Unnamed Tributary to Clear Fork, Unnamed Tributary to Buffalo Fork, and Buffalo Fork (the southern basins), Coal River Basin, mountaintop coal-mining region, southern West Virginia—*Continued*.

FLOOD OF JULY 8–9, 2001

In the early morning of July 8, 2001, a thunderstorm complex formed in central West Virginia from outflow winds of an earlier group of thunderstorms that moved across northern West Virginia. The thunderstorm complex then moved into southeastern West Virginia by late morning on July 8, and by early afternoon, 3 to 6 in. of rainfall had fallen in 5 to 6 hours. The hydrologic service area of the National Weather Service office in Charleston, West Virginia, used radar images and field-observer reports to prepare a map showing the total rainfall from the morning of July 8 through the morning of July 9. Figure 2 is a sub-area of the map prepared by the National Weather Service with the addition of streams, basin boundaries, one town, and one gaging station. Figure 2 shows that the total rainfall in the study area was between 4 and 5 in. (John Sikora, National Weather Service, written commun., 2001).

Flooding from the thunderstorm complex was caused primarily by intense rainfall on dry ground. Rainfall totals for the storm were nearly equal to the monthly average of about 5 in. (John Sikora, written commun., 2001). The most severe flooding occurred in the headwaters of the Coal, Guyandotte, and Tug Fork Rivers, where recurrence intervals of peak discharges (the average time between floods that equal or exceed a particular peak discharge) at some locations were at or greater than 100 years. The gaging station Clear Fork at Whitesville (USGS station number 03198350, drainage area 62.8 mi^2) is downstream from the study area (fig. 2), and the indirectly-measured peak discharge (calculated by means of the same techniques as the peak discharges given in this study) at this station during this storm was determined to have a recurrence interval of more than 100 years.

INDIRECT MEASUREMENT OF PEAK DISCHARGES

Indirect measurements of peak discharges for the July 8–9, 2001, flood at the six study sites were based on the techniques described by Benson and Dalrymple (1967), and were calculated by the computer program developed by Fulford (1994). Generally, high-water marks are identified along the stream banks, a land survey of high-water marks and stream cross sections is conducted, estimates of channel roughness are made with Manning's roughness coefficients, and a computer program is used to apply open-channel-flow equations to determine discharge. This indirect method of measuring peak discharges is commonly referred to as the "slope-area method." Data on rainfall totals and intensities are not necessary to compute peak discharges. Indirectly measured peak discharges at the six study sites ranged from 45 to 228 ft^3/s (table 1).

Benson and Dalrymple (1967) discuss the errors associated with the slope-area method of computing peak discharges by comparing the computed discharges to known discharges. Slope-area measurements of peak discharges during the May–June 1948 floods in the Columbia River Basin were made at 22 locations where the discharges were known. There was a 25-percent difference at one location. There was a maximum difference of 15.6 percent and an average of 6.7 percent at the remaining 21 locations. Errors associated with the slope-area measurements made for this study probably have similar magnitudes.

The site MT65C is at the outflow of a sediment pond downstream from two valley fills. The drainage area above MT65C, 0.189 mi^2 (121 acres) is a revised value from the 0.102 mi^2 (65 acres) previously published by Wiley and others (2001). The omission of one of the two valley fills resulted in the incorrect previously published drainage area.

Manning's roughness coefficients are the only values used in the discharge calculation that are not directly measured, except for the interpretation of high-water marks. Manning's roughness coefficients were estimated by comparison of field observations and photographs of the stream channels at the sites to photographs taken at locations with measured roughness coefficients (Barnes, 1967).

The sensitivity of calculated discharge values to 10-percent increases and decreases in the roughness coefficients was evaluated (table 2). The magnitude of 10 percent was selected because most experienced surface-water hydrologists could probably estimate Manning's roughness coefficient within 10 percent of the actual value. The largest change in discharge was that calculated at site MT66, Buffalo Fork, where a 10-percent decrease in roughness increased discharge by about 12 percent (peak discharge was calculated to increase from 224 to 251 ft^3/s). No sensitivity tests were performed based on the interpretation of high-water marks.

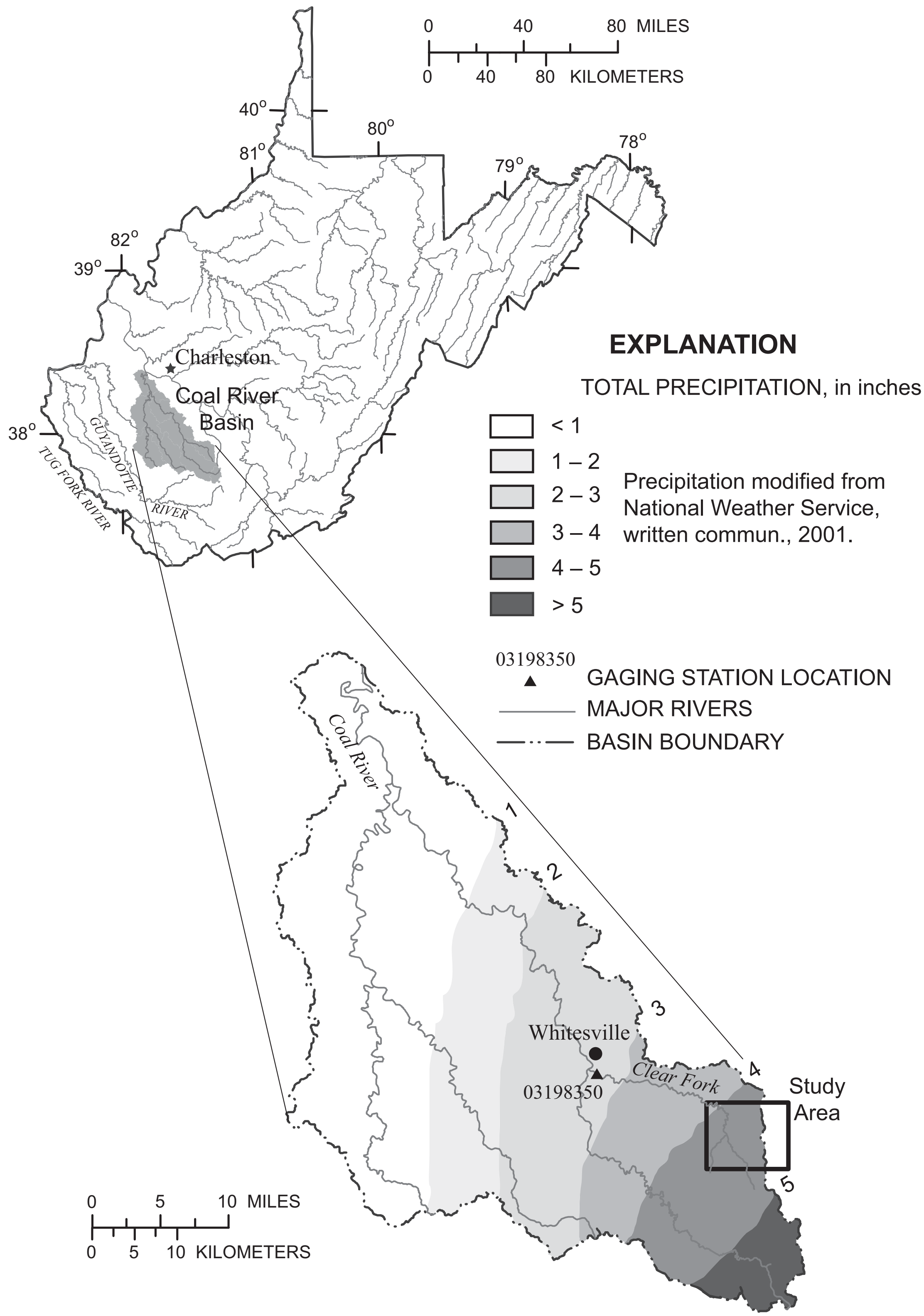

Figure 2. Total rainfall from the morning of July 8 through the morning of July 9, 2001, in the headwaters of Clear Fork, Coal River Basin, mountaintop coal-mining region, southern West Virginia.

Table 1. Indirectly measured peak discharges and estimated recurrence intervals for the flood of July 8–9, 2001, at the six study sites in the headwaters of Clear Fork, Coal River Basin, mountaintop coal-mining region, southern West Virginia

[USGS(n) identifies a site selected by the U.S. Geological Survey for this study; MT(n) indicates that the site being used in this study was part of the Mountaintop Mining/Valley Fill Environmental Impact Statement study, where (n) is a unique numeric or alphanumeric identifier. Flood-recurrence interval was determined by using Wiley and others (2000) and the sensitivity of calculated discharges to Manning's roughness coefficients]

Basin name	Site identifier	Latitude ° ′ ″	Longitude ° ′ ″	Drainage area, in square miles	Indirectly measured peak discharge, in cubic feet per second	Estimated flood recurrence interval, in years
Basins without valley fills						
Unnamed Tributary to Lick Run	USGS1	37 52 36	81 18 31	0.461	140	25
Unnamed Tributary to Clear Fork	USGS2	37 52 42	81 19 50	.360	90	10
Ewing Fork[a]	USGS3	37 54 45	81 19 34	1.17	228	10
Basins with valley fills						
Unnamed Tributary to Buffalo Fork	MT65C	37 53 48	81 19 38	[b].189	113	[c]>100
Buffalo Fork	MT66	37 53 47	81 19 09	.583	224	[c]50–100
Reeds Branch	MT76	37 54 28	81 18 46	.462	45	[c]<2

[a]Site is near MT69, which was used to prepare the Mountaintop Mining/Valley Fill Environmental Impact Statement (Wiley and others, 2001).

[b] Drainage area was revised from the 65 acres (0.102 square miles) used to prepare the Mountaintop Mining/Valley Fill Environmental Impact Statement and is the value published by Wiley and others (2001).

[c]Flood-recurrence interval of indirectly measured peak discharge was computed as though the peak discharge was that from a rural stream without the influence of valley fills.

Table 2. Sensitivity of indirectly measured peak discharges to Manning's roughness coefficients for the flood of July 8–9, 2001, at the six study sites in the headwaters of Clear Fork, Coal River Basin, mountaintop coal-mining region, southern West Virginia

[USGS(n) identifies a site selected by the U.S. Geological Survey for this study; MT(n) indicates that the site being used in this study was selected by group of agencies for preparation of the Mountaintop Mining/Valley Fill Environmental Impact Statement, where (n) is a unique alphanumeric identifier]

Basin name	Site identifier	Indirectly measured peak discharge, in cubic feet per second	Range of Manning's roughness coefficient	Discharge calculated with a 10 percent decrease in Manning's roughness, in cubic feet per second	Discharge calculated with a 10 percent increase in Manning's roughness, in cubic feet per second
Basins without valley fills					
Unnamed Tributary to Lick Run	USGS1	140	0.065–0.068	154	127
Unnamed Tributary to Clear Fork	USGS2	90	0.050–0.060	100	81
Ewing Fork[a]	USGS3	228	0.055–0.060	253	207
Basins with valley fills					
Unnamed Tributary to Buffalo Fork	MT65C	113	0.070–0.080	124	103
Buffalo Fork	MT66	224	0.055–0.080	251	201
Reeds Branch	MT76	45	0.060–0.062	49	41

[a]Site is near MT69, which was used to prepare the Mountaintop Mining/Valley Fill Environmental Impact Statement (Wiley and others, 2001).

Estimates of flood-recurrence intervals (table 1) at the sites in basins without a valley fill (USGS1, USGS2, and USGS3) were made by comparing the indirectly measured peak discharges to estimated peak discharges determined from published flood-frequency estimating equations (Wiley and others, 2000) (fig. 3). Consideration was given to the sensitivity of calculated discharges to Manning's roughness coefficients (table 2). Flood-recurrence intervals were calculated for the sites in the basins with valley fills (MT65C, MT66, and MT76) as though the peak discharges were those from rural streams without the influence of valley fills (table 1 and fig. 3). Estimates of recurrence intervals of peak discharges for the six study sites were between less than 2 years and more than 100 years.

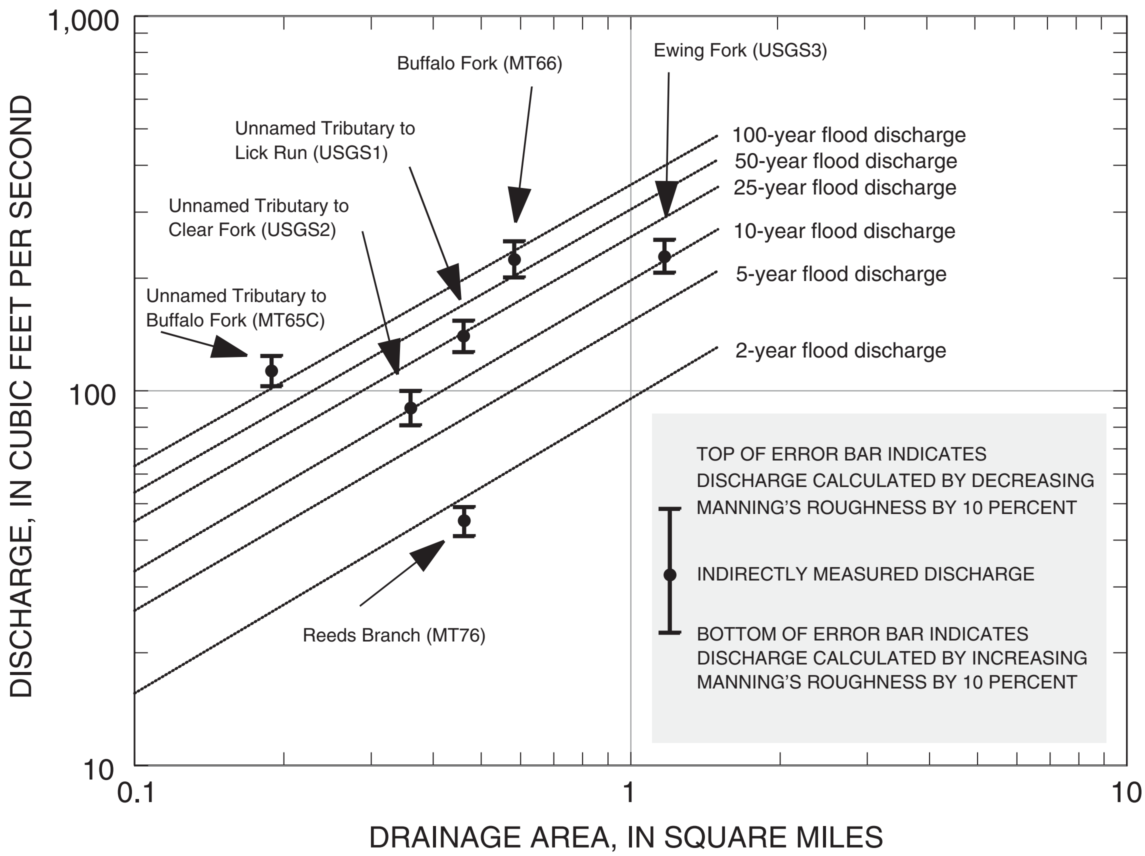

Figure 3. Comparison among indirectly measured discharges and selected recurrence-interval flood discharges at the six study sites in the headwaters of Clear Fork, Coal River Basin, mountaintop coal-mining region, southern West Virginia. Recurrence-interval flood discharges are those for rural streams without the influence of valley fills (Wiley and others, 2000).

COMPARISON OF PEAK DISCHARGES AMONG SITES IN BASINS WITH AND WITHOUT VALLEY FILLS

Flood peaks in small headwater basins with valley fills constructed from mountaintop-removal mining are affected by changes in surface slopes and permeability, deforestation, and the construction of sediment ponds downstream from the toe of the fill. The lower surface slope of the valley fill compared to that of the original mountainside tends to increase the travel time of overland runoff and facilitate infiltration. Reclaimed surfaces (and previous grades of the valley fill and surrounding spoil areas, particularly previous grades resulting from lift-construction techniques used to build the valley fill) commonly are formed of small particles compacted by equipment traffic and the sorting of materials due to gravity, and the resulting lower permeability tends to decrease the travel time of overland runoff (Wunsch and others, 1996). The valley fill and adjacent spoil areas are recharged where boulders exposed to the surface facilitate infiltration, where streams and springs run directly into the fill, at the contact point between the edge of the fill and highwalls or near-surface tectonically induced fractures, at active mining areas, and where specially designed ponds collect overland runoff and direct the flow deep into the fill (Kipp and Dinger, 1991; Wunsch and others, 1992; and Wunsch and others, 1996). Deforestation from logging generally results in increases in peak discharges during the growing season and fall recharge period, and has minimal impact on peak discharges during the dormant season if management practices are implemented to decrease runoff from roads and skid trails. Snow, antecedent soil moisture, and probably other factors also affect the peak discharge from deforested areas (Reinhart and others, 1963). Generally, the greatest peak discharges from small drainage areas result from intense, local thunderstorms during the growing season, rather than from frontal systems and tropical cyclones normally associated with the greatest peak discharges for large drainage areas (Doll and others, 1963). Ponds constructed at the bases of valley fills can collect and retain runoff, and thus cause a decrease in peak discharges (Curtis, 1979). The magnitude of the decrease in peak discharge depends on the flood-storage volume and the design for the outfall of the pond.

The study plan was based on the assumption that the six study basins were within an area (7 mi^2) small enough that rainfall intensities and totals would be approximately equal, but this assumption was determined invalid. The flood-recurrence intervals for the three basins without valley fills should be approximately equal if the assumption was correct. Table 1 shows that the flood-recurrence intervals for the three basins without valley fills (USGS1, USGS2, and USGS3) are not equal. The flood frequencies were between 10 and 25 years with the greatest flood frequency at the southernmost basin, USGS1.

The flood-recurrence intervals for the three basins with valley fills (peak discharges were treated in the computation like those from rural streams without the regulation of valley fills) were between less than 2 years and more than 100 years (table 1). The smallest recurrence interval was at MT76, the site in the northernmost basin with no active surface mining and a reclaimed valley fill, which was the largest valley fill in this study. The greatest recurrence interval was at MT65C, the site in a basin with active surface mining and one reclaimed and one unreclaimed valley fill, which was the only unreclaimed valley fill in this study.

Changes in hydrologic conditions and responses resulting from changes in surface slopes and permeability, deforestation, the construction of sediment ponds, other reclamation practices, and basin and climate conditions (such as basin orientation, size and composition of the valley fill, local geology, antecedent soil moisture, and precipitation intensities and totals) in basins with valley fills are not adequately understood.

SUMMARY

The U.S. Geological Survey, in cooperation with the Office of Surface Mining Reclamation and Enforcement, investigated the effects of mountaintop-removal mining with valley fills on the peak discharges for the flood of July 8–9, 2001. The study area included six small basins (drainage areas ranging from 0.189 to 1.17 mi^2) within an area of about 7 mi^2 in the headwaters of Clear Fork of the Coal River in the Appalachian Plateaus Physiographic Province of southern West Virginia.

In the early morning of July 8, 2001, a thunderstorm complex formed in central West Virginia from outflow winds of an earlier group of thunderstorms that had moved across northern West Virginia. Flooding from the thunderstorm complex was primarily caused by intense rainfall on dry ground, and rainfall totals were nearly equal to the monthly average of about 5 in.

Indirect peak-discharge measurements were made at three sites in basins with valley fills and three sites in basins without valley fills. Flood-recurrence intervals were estimated by comparing the indirectly measured peak discharges to peak discharges determined from equations for estimating magnitudes of floods for different recurrence intervals in rural, unregulated streams of West Virginia. The sites without valley fills had peak discharges with about 10- to 25-year recurrence intervals; this result indicates that rainfall intensities and totals varied among the study basins. The flood-recurrence intervals for the three basins with valley fills were determined as though the peak discharges were those from rural streams without the influence of valley fills, and were between less than 2 years and greater than 100 years.

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