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

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CONVERSION FACTORS

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

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

°F = (1.8)°C + 32 °C = (°F-32)/1.8

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

DATUMS

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

WATER-QUALITY ABBREVIATIONS

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

ACRONYMS

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

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By Katherine S. Paybins

Abstract

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

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

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

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

INTRODUCTION

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

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

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

Purpose and Scope

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

Description of Study Area

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

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

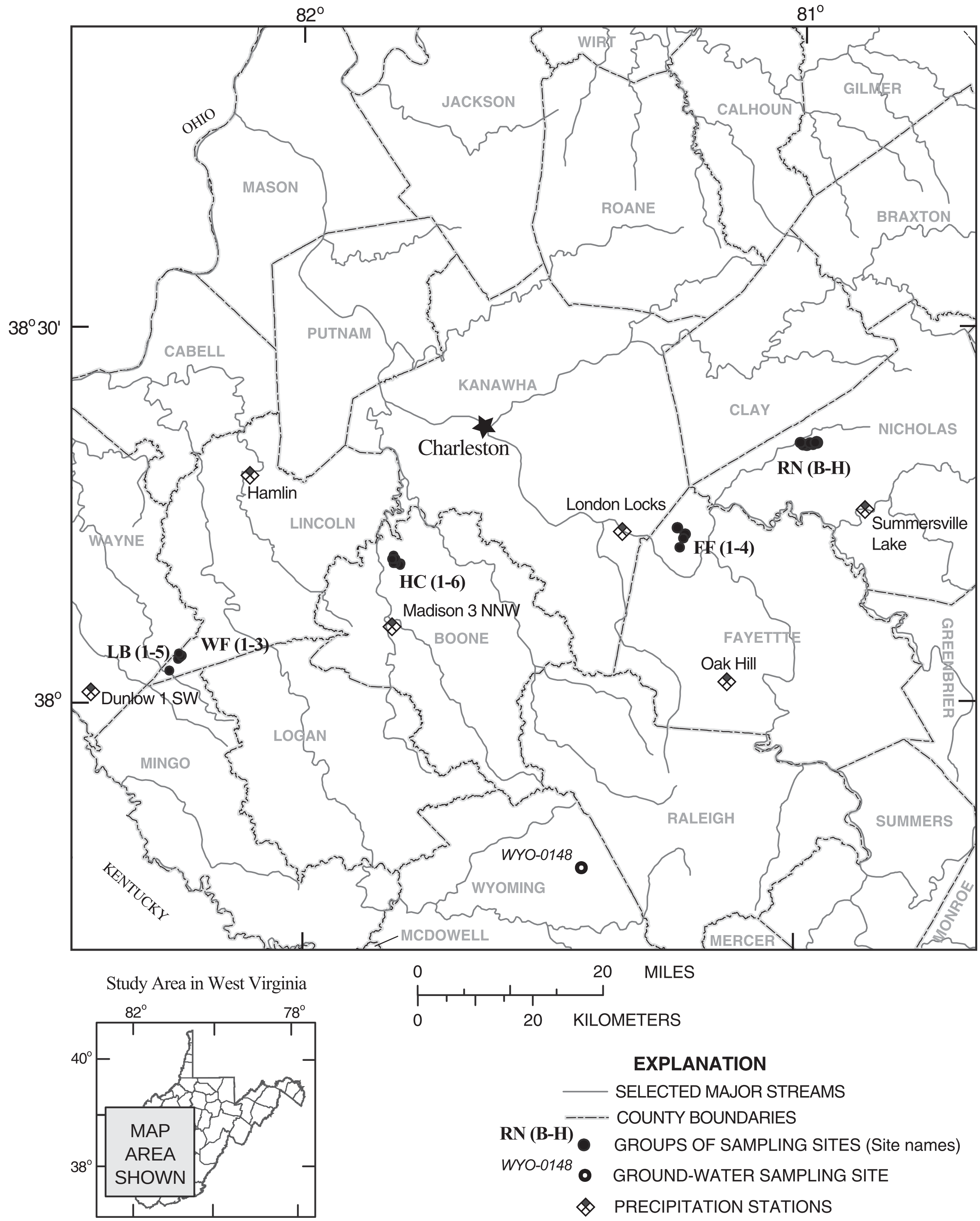


Figure 1. Locations of the study-area groups of sampling sites in the headwater streams of the mountaintop coal- mining region of southern West Virginia, 2000–01.

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

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

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

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

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

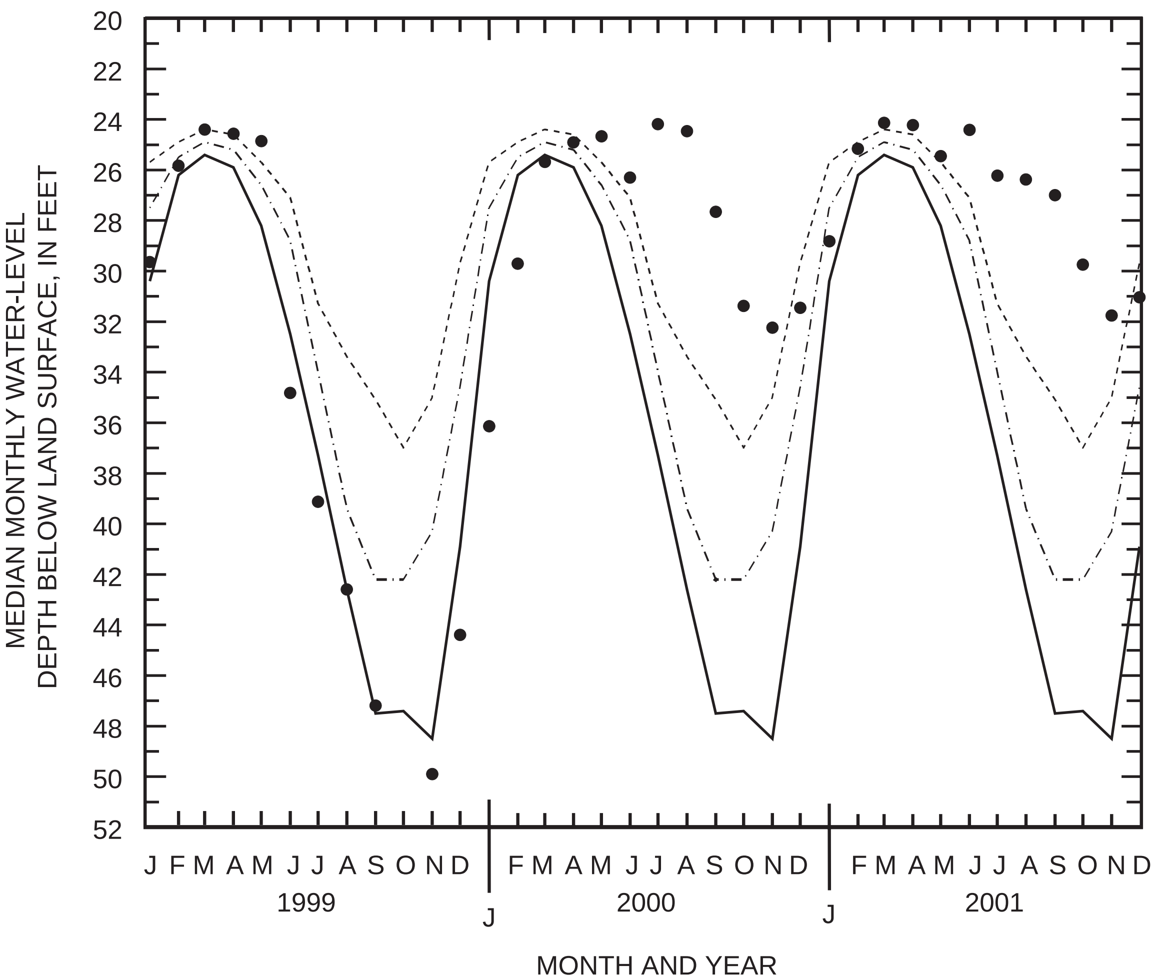
Precipitation station	Group of sites closest to precipitation station	October 1999 through March 2000	April 2000 through September 2000	October 2000 through March 2001	April 2001 through September 2001	Normal monthly precipitation		Normal annual precipitation
						October–March	April–September	
Dunlow 1 SW	LB, WF	10.06	29.69	[1]4.83	20.96	20.86	24.85	45.71
Hamlin	HC, LB, WF	19.56	27.95	[1]8.96	24.47	20.14	24.26	44.40
London Locks	FF	15.85	36.30	12.38	29.19	19.76	25.50	45.26
Madison 3 NNW	HC	12.55	31.76	[1]10.18	[1]25.00	20.73	27.11	47.84

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

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

Precipitation station	Group of sites closest to precipitation station	October 1999 through March 2000	April 2000 through September 2000	October 2000 through March 2001	April 2001 through September 2001	Normal monthly precipitation		Normal annual precipitation
						October–March	April–September	
Oak Hill....................	FF	11.95	33.86	11.25	30.69	20.62	25.59	46.21
Summersville Lake ...	RN	12.94	36.93	12.10	32.61	20.65	26.83	47.48

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



Definitions of Perennial, Intermittent, and Ephemeral Streams

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

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

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

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

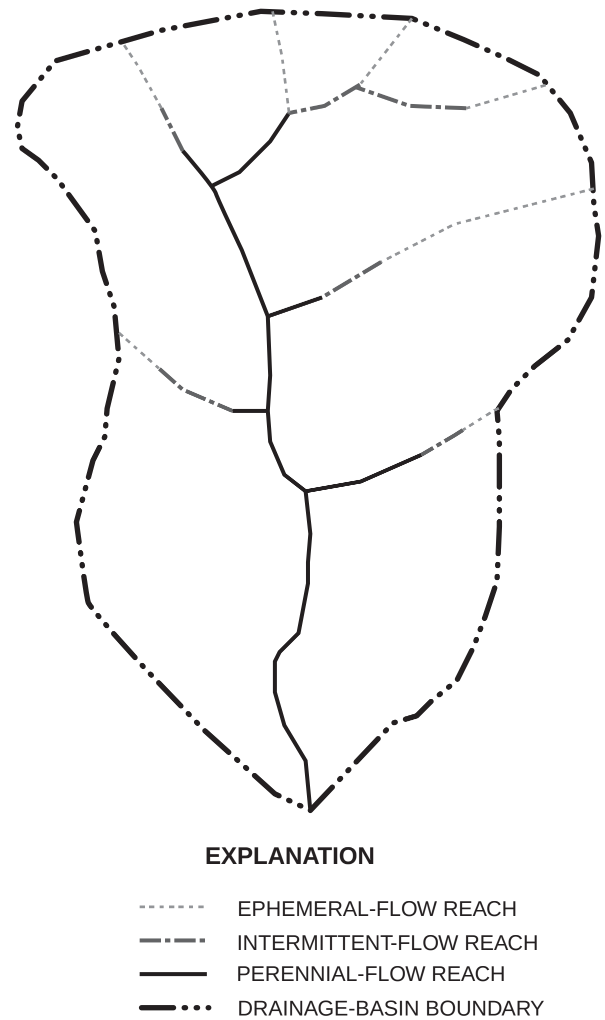


Figure 3. Ephemeral-, intermittent-, and perennial-flow patterns typical for the mountaintop coal-mining region of southern West Virginia.

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

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

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

Acknowledgments

The author thanks USGS and OSM colleagues for their contributions to the field work and reviews. The USGS appreciates the time given and knowledge of the study area shared by Randall Maggard (Pen Coal Inc.), John McDaniel (Arch Coal, Inc.), Francis Meadows (Alex Energy, Inc.), Frank Rose (Pittston/Appalachian Co.), and Roger Wolfe (formerly of Mid-Vol Leasing, Inc.). The USGS is also grateful to David Vandelinde of the WVDEP for his assistance in securing contacts at the research sites.

STUDY DESIGN AND DATA COLLECTION

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

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

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

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

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

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

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

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

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

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

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

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

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

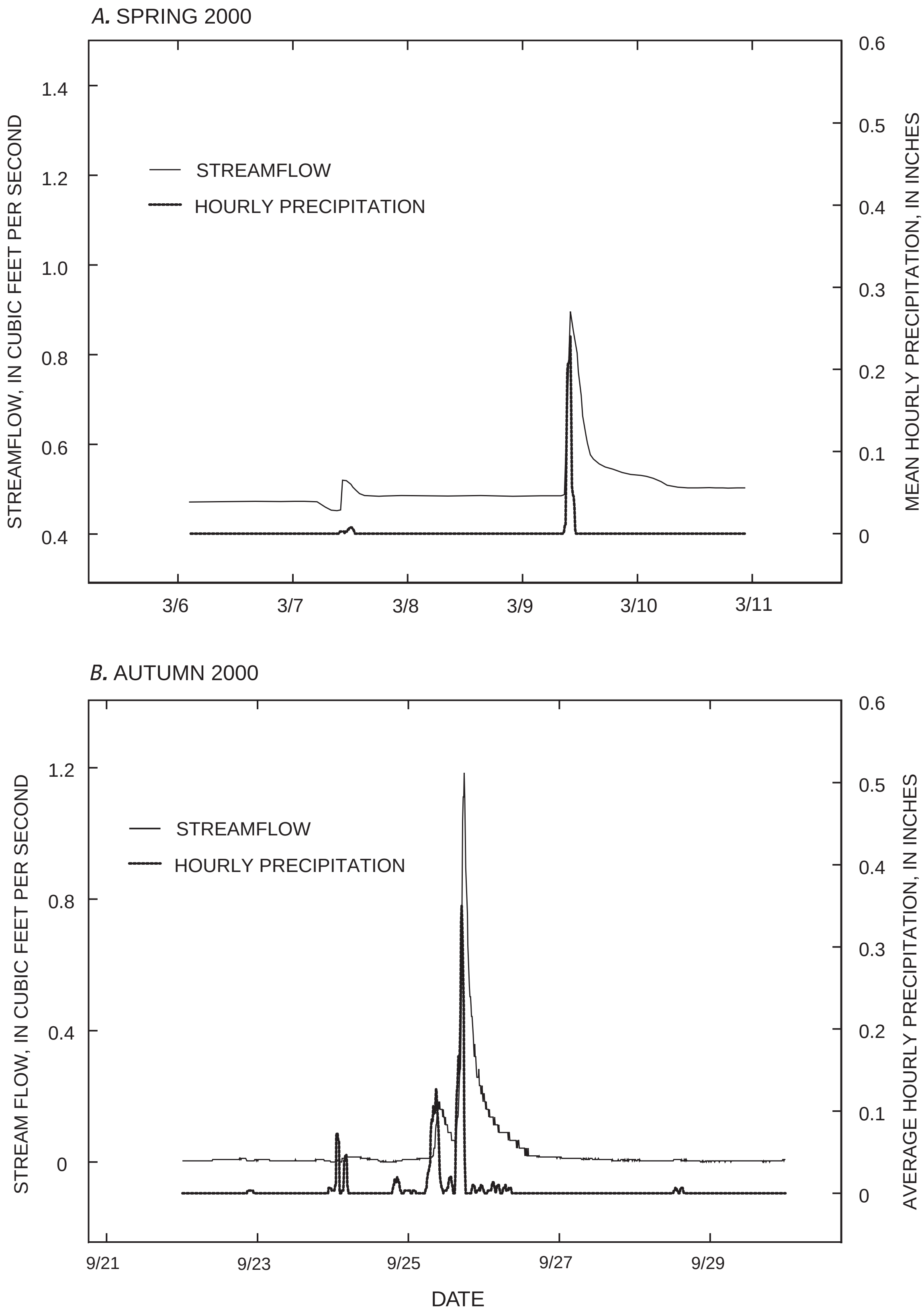


Figure 4. Streamflow and precipitation for the streamflow-gaging station (03204210) on a small stream near Mud, in the mountaintop coal-mining region of southern West Virginia during (*A*) a spring 2000 precipitation event, and (*B*) an autumn 2000 precipitation event.

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

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

CHARACTERISTICS OF HEADWATER STREAMS

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

Drainage Areas with Intermittent Flow

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

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

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

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

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

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

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

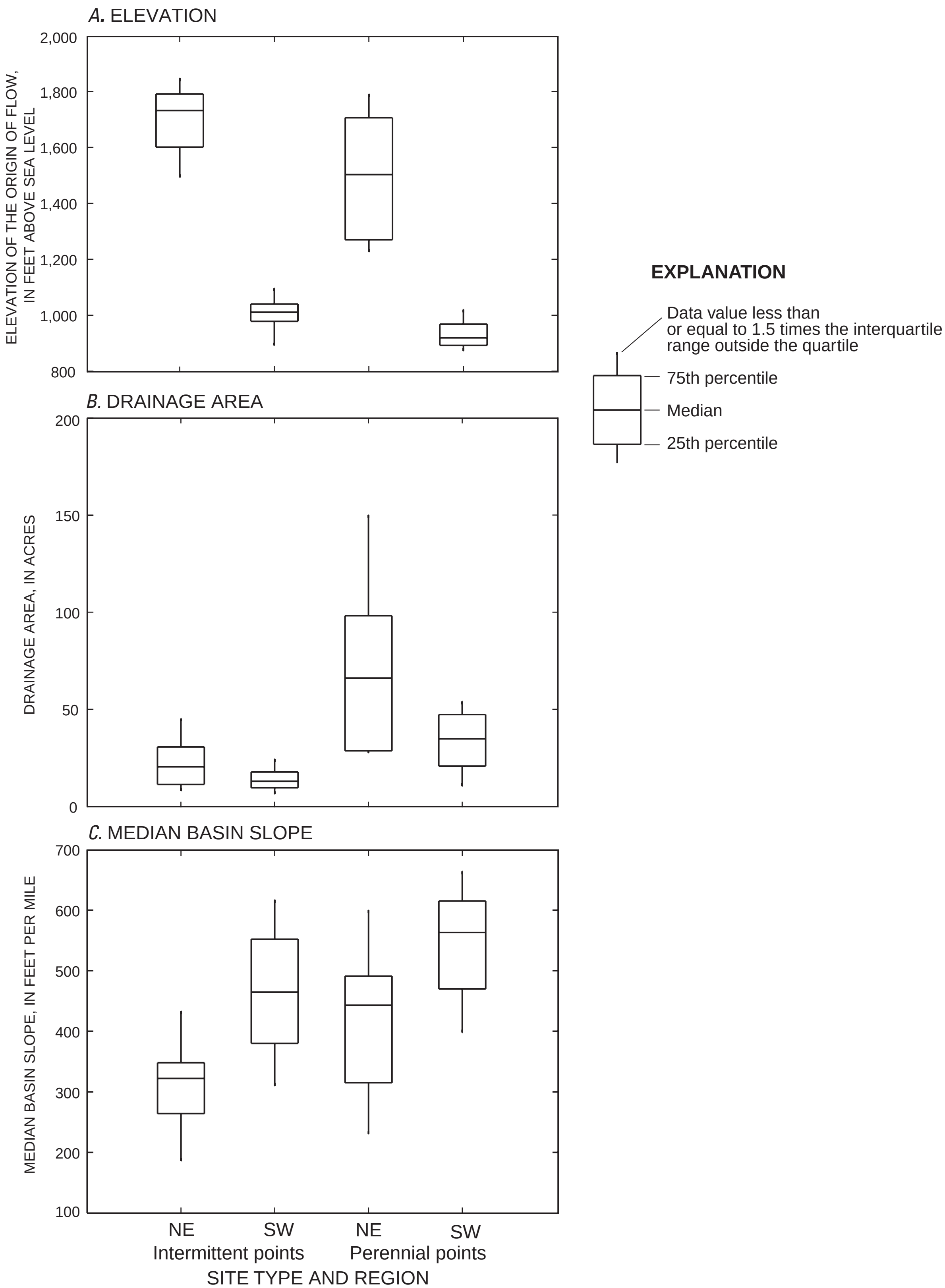


Figure 5. Distribution of (*A*) elevation, (*B*) drainage area, and (*C*) median basin slope for intermittent and perennial points in headwater streams of the mountaintop coal-mining region of southern West Virginia, 2000–01.

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

Drainage Areas with Perennial Flow

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

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

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

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

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

Temporal Variability in Intermittent and Perennial Drainage Areas

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

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

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

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

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

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

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

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

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

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

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

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

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

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

SUMMARY AND CONCLUSIONS

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

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

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

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

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

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

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

REFERENCES CITED

Black, P.E., 1991, Watershed hydrology: Prentice Hall Advanced Reference Series, Physical and Life Sciences, 408 p.

Dieterich, M., and Anderson, N.H., 2000, The invertebrate fauna of summer-dry streams in western Oregon: Archiv fur Hydrobiologie, v.147, p. 273-295.

Eash, D.A., 1994, A geographic information system procedure to quantify drainage-basin characteristics: Water Resources Bulletin, v. 30, no. 1, p. 1-8.

Feminella, J.W., 1996, Comparison of benthic macroinvertebrate assemblages in small streams along a gradient of permanence: Journal of the North American Benthologic Society, v. 15, no.4, p. 651-669.

Fenneman, N.M., 1938, Physiography of Eastern United States: New York, McGraw-Hill, 714 p.

Fenneman, N.M., and Johnson, D.W., 1946, Physical divisions of the United States: U.S. Geological Survey Physiography Committee Special Map, scale 1:7,000,000.

Fitzpatrick, F.A., Waite, I.R., D'Arconte, P.J., Meador, M.R., Maupin, M.A., and Gurtz, M.E., 1998, Revised methods for characterizing stream habitat in the National Water-Quality Assessment Program: U.S. Geological Survey Water-Resources Investigations Report 98-4052, 67 p.

Helvey, J.D., and Patric, J.H., 1965, Canopy and litter interception of rainfall by hardwoods of eastern United States: Water Resources Research, v. 1. no. 2, p. 193-206.

Hewlett, J.D., 1982, Principles of forest hydrology: The University of Georgia Press, 183 p.

Horton, R.E., 1932, Drainage-basin characteristics: American Geophysical Union Transactions, p. 350-361.

Langbein, W.B., and Iseri, K.T., 1960, General introduction and hydrologic definitions, Manual of Hydrology: Part 1. General Surface-water Techniques: U.S. Geological Survey Water-Supply Paper 1541-A, p. 18.

Legal Information Institute, 2002a, Code of Federal Regulations, chapter 30, accessed August 2002 at http://lula.law.cornell.edu/cfr/cfr.php?title=30&type=chapter&value=7

_____, 2002b, Surface Mining Control and Reclamation Act, accessed April 2002 at http://www4.law.cornell.edu/uscode/30/ch25.html

Leopold, L.B., 1994, A View of the River: Harvard University Press, 298 p.

Messinger, T. and Hughes, C.A., 2000, Environmental setting and its relations to water quality in the Kanawha River Basin: U.S. Geological Survey Water- Resources Investigations Report 00-4020, 57 p.

U.S. Department of Commerce, 1960, Climate of West Virginia: Weather Bureau, Climatography of the United States, no. 60-46, 15 p.

_____, 2000, Climatological data summary, West Virginia 1999: National Climatic Data Center, v. 107, n. 13, 22 p.

_____, 2001, Climatological data summary, West Virginia 2000: National Climatic Data Center, v.108, n.13, 23 p.

_____, 2002a, Climatological data summary, West Virginia 2001: National Climatic Data Center v. 109, n.13, 26 p.

_____, 2002b, Climatography of the United States, Monthly normals of temperature, precipitation, and heating and cooling degree days 1971-2000: Weather Bureau, No. 81 (46), 23 p.

U.S. District Court for the Southern District of West Virginia, 1999, Bragg v. Robertson 2:98-0636: accessed March 2002, at http://www.fedcourtwvsd.com/.

U.S. Environmental Protection Agency, 1999, Mountaintop Mining: accessed February 2002, at http://www.epa.gov/region3/mtntop

U.S. Geological Survey, 1970, The national atlas of the United States of America: U.S. Geological Survey, 417 p.

_____, 1980, Technical instructions of the National Mapping Division, map editing, provisional chapter 5C1: U.S. Department of the Interior, Geological Survey, p. 16.

_____, 1999, National Elevation Dataset, West Virginia subset: U.S. Geological Survey, EROS data-center. Accessed August 2002, at ftp://centauri.geo.wvu.edu/pub/Clearinghouse/DEM/NED/

Ward, S.M., Taylor, B.C., and Crosby G.R., 2001, Water resources data–West Virginia, water year 2000: U.S. Geological Survey Water-Data Report WV-00-1, 262 p.

_____, 2002, Water resources data–West Virginia, water year 2001: U.S. Geological Survey Water-Data Report WV-01-1, 255 p.

West Virginia Department of Environmental Protection, 1998, Surface rock type–rock units: digital coverage of rock type of West Virginia, 1968, accessed August 2002, at ftp://ftp.wvgis.wvu.edu/pub/Clearinghouse/rock type/wvgeol.zip

West Virginia Department of Environmental Protection, 2002, digital GIS data of valley fills from permit maps, accessed May 2002, at http://129.71.240.42/data/omr.html

West Virginia Office of Miners' Health, Safety and Training, 2000, West Virginia coal facts: accessed February 2002, at http://www.state.wv.us/mhst/wvcoalfacts.htm.

Williams, D.D., 1996, Environmental constraints in temporary fresh waters and their consequences for the insect fauna: Journal of the North American Benthologic Society, vol. 15, no. 4, p. 634-650.

Wyrick, G.G., and Borchers, J.W., 1981, Hydrologic effects of stress-relief fracturing in an Appalachian Valley: U.S. Geological Survey Water-Supply Paper 2177, 51 p.