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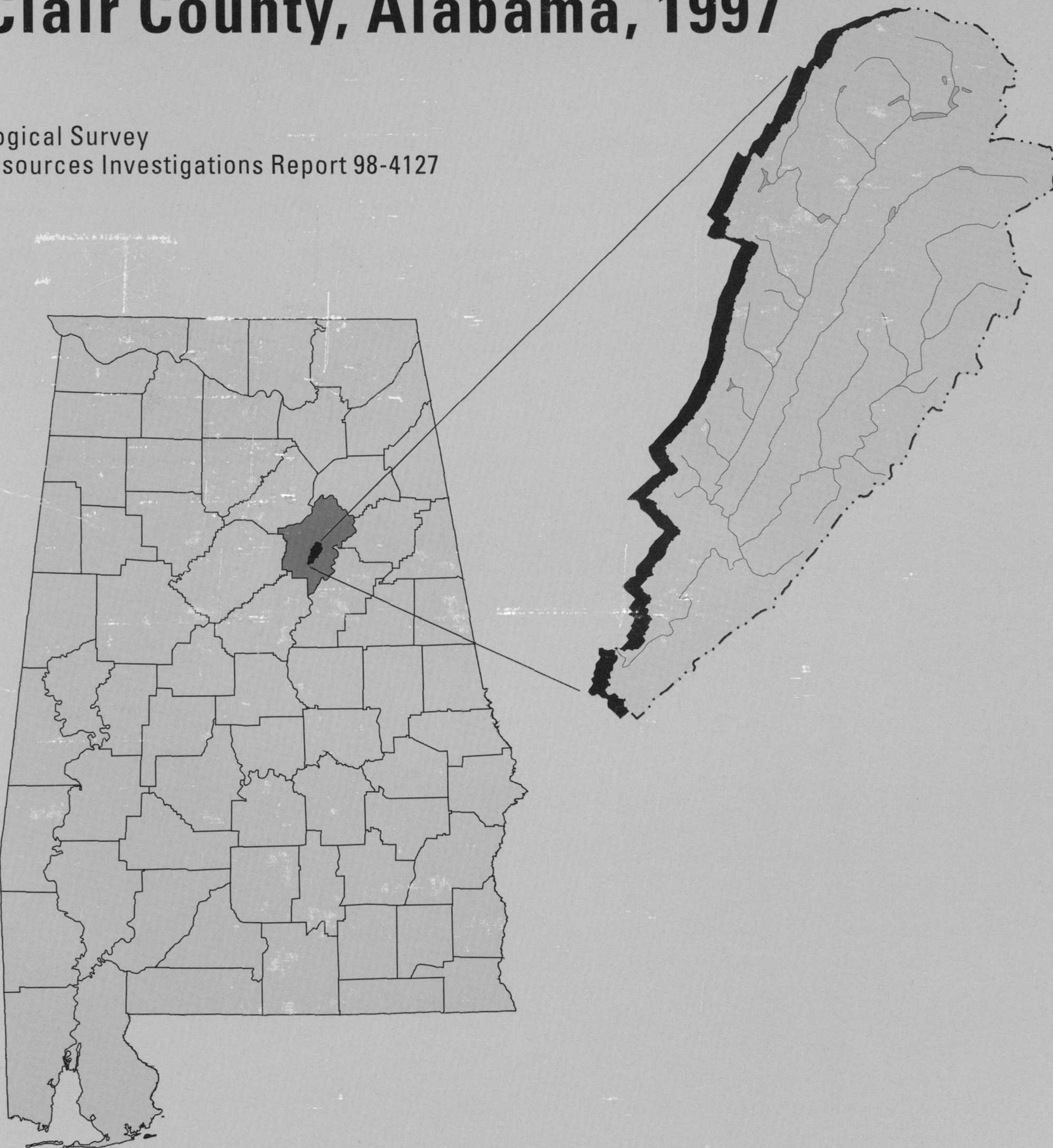
Streamflow, Water-Quality, and Biological Conditions in the Big Black Creek Basin, St. Clair County, Alabama, 1997

U.S. Geological Survey
Water–Resources Investigations Report 98-4127



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

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By C.A. JOURNEY, A.E. CLARK, and V.E. STRICKLIN

U.S. GEOLOGICAL SURVEY

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Montgomery, Alabama
1998

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

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ACRONYMS AND ABBREVIATIONS:

ADEM	Alabama Department of Environmental Management
BI	biotic index
COALQUAL	U.S. Geological Survey coal quality data base
CPOM	Coarse particulate organic matter
EPT	Ephemeroptera, Plecoptera, and Trichoptera
MRL	minimum reporting level
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	volatile organic compound
WATEQ4F	computer translation program for the geochemical model WATEQ2
mg/L	milligram per liter
mg/kg	milligram per kilogram
µg/L	microgram per liter
µg/kg	microgram per kilogram
µS/cm	microsiemens per centimeter at 25 °C as a measure of specific conductance

Streamflow, Water-Quality, and Biological Conditions in the Big Black Creek Basin, St. Clair County, Alabama, 1997

By C.A. Journey, A.E. Clark, *and* V.E. Stricklin

ABSTRACT

In 1997 synoptic streamflow, water-quality, and biological investigations in the Big Black Creek Basin were conducted by the U.S. Geological Survey in cooperation with the City of Moody, St. Clair County, and the Birmingham Water Works Board. Data obtained during these synoptic investigations provide a one-time look at the streamflow and water-quality conditions in the Big Black Creek Basin during a stable, base-flow period when streamflow originated only from ground-water discharge. These data were used to assess the degree of water-quality degradation in the Big Black Creek Basin from land-use activities in the basin, including leakage of leachate from the Acmar Regional Landfill. Biological data from the benthic invertebrate community investigation provided an assessment of the cumulative effects of stream conditions on organisms in the basin.

The synoptic measurement of streamflow at 28 sites was made during a period of base flow on August 27, 1997. Two stream reaches above the landfill lost water to the ground-water system, but those below the landfill had significantly higher ground-water gains. If significant leakage of leachate from the landfill had occurred during the measurement period, the distribution of ground-water discharge suggests that leachate would travel relatively short distances before resurfacing as ground-water discharge to the stream.

Benthic invertebrate communities were sampled at four sites in the Big Black Creek Basin during July 16–17, 1997. Based on Alabama Department of Environmental Management criteria and on comparison with a nearby unimpaired reference site, the benthic invertebrate communities at the sites sampled were considered unimpaired or only slightly impaired during the sample period. This would imply that landfill and coal-mining activities did not have a detrimental effect on the benthic invertebrate communities at the time of the study.

Synoptic water-column samples were collected at nine sites on Big Black Creek and its tributaries at the same time that the synoptic streamflow measurements were made. Trace-element and organic compound concentrations in the stream water were below established water-quality standards and criteria for the State of Alabama, with the exception of secondary (aesthetic) drinking-water levels for iron and manganese. Oil and grease concentrations detected in bed sediments were below the corrective action limit of 100 milligrams per kilogram. No significant increases in chloride, specific conductance, total dissolved solids, oil and grease, color, or biochemical oxygen demand were observed at sites downgradient from the landfill.

Ground-water samples were collected from three drive-point wells in the vicinity of the landfill. These samples were analyzed for a suite of volatile organic compounds. The solvent 1,1-dichloroethane (the same solvent detected in the ground-water monitoring system at the landfill) was detected in a sample from a drive-point well downgradient from the landfill—an indication of the potential risk of landfill-derived contamination migrating toward Big Black Creek.

No distinguishing trend or pattern of contamination was identified that could be attributed solely to landfill activities. Landfill activities did not appear to contribute significant contamination to Big Black Creek during these streamflow conditions. Any contaminant contribution from coal-mining activities in the basin may have served to mask any leachate contributions from the landfill; however, the overall effects on stream water and benthic invertebrate communities apparently were only minimal.

INTRODUCTION

The Big Black Creek Basin is in the Valley and Ridge physiographic province in the southwestern corner of St. Clair County, Alabama (fig. 1). The basin drains extensively folded and faulted sedimentary strata in the northeastern portion of the Cahaba Coal Field, the oldest coal mining area in Alabama (Pashin and others, 1995). Abandoned surface- and subsurface-coal mines, mine tailings, spoil piles, and coal washes are prevalent within the basin.

The Acmar Regional Landfill is located on 765 acres in the Big Black Creek Basin. The active landfill has been permitted by the Alabama Department of Environmental Management (ADEM) since 1983 for the disposal of mixed-municipal solid waste into lined waste cells that encompass 31 acres. Most of the remaining acreage consists of partially wooded, moderately to steeply sloping terrain. The active waste cells are bordered to the north, east, and west by portions of Big Black Creek, which flows southeast of the landfill to its confluence with the Cahaba River, a source of drinking water for the City of Birmingham.

Much of the landfill property, including the active cells, is underlain by abandoned room-and-pillar coal mines that were operated by the Alabama Fuel and Iron Company from about 1919 to 1948 (Gallet and Associates, 1996). Surface-mining activities at the landfill occurred from 1979 to 1981 (Gallet and Associates, 1996).

Acmar Regional Landfill submitted a request to the ADEM for modification of the mixed-municipal solid-waste permit. The permit modification would allow the construction of an additional 335-acre municipal waste site and a 100-acre construction and demolition waste site adjacent to the active landfill.

Local city and county officials expressed concern that the ground- and surface-water systems in the Big Black Creek Basin may be susceptible to water-quality degradation from leakage of landfill-derived leachate. As part of the U.S. Geological Survey (USGS) ongoing regional studies of anthropogenic effects on water quality, the USGS conducted a synoptic streamflow, water-quality, and biological investigation in the Big Black Creek Basin to provide information relative to those concerns. The investigation was performed in cooperation with the City of Moody, St. Clair County, and the Birmingham Water Works Board.

Purpose and Scope

This report summarizes the streamflow, water-quality, and benthic invertebrate community data collected in the Big Black Creek Basin during three synoptic field surveys. The streamflow and water-quality data provide an initial assessment of stream conditions during one low-flow period. The benthic invertebrate community data provide an assessment of the cumulative effects of stream conditions on organisms in the basin. The observed streamflow, water-quality, and benthic invertebrate community conditions in Big Black Creek were evaluated to determine to what extent these conditions were affected by mining or landfill activities.

The investigation of the Big Black Creek Basin was conducted in four parts beginning in April 1997 and ending in August 1997:

(1) Literature review and field reconnaissance to identify appropriate sites for data collection.

(2) Synoptic survey and assessment of benthic invertebrate communities at a subset of four of the nine selected water-quality sites in Big Black Creek and its tributaries to determine community structure and health.

(3) Synoptic streamflow investigation at 28 sites during a period of base flow (low water table; no runoff) to estimate discharge from the ground-water system to the stream and to identify gaining or losing stream reaches.

(4) Synoptic investigation of stream-water quality at nine sites during this same period of base flow to assess the water-quality conditions in the stream. Bed-sediment samples were taken at seven

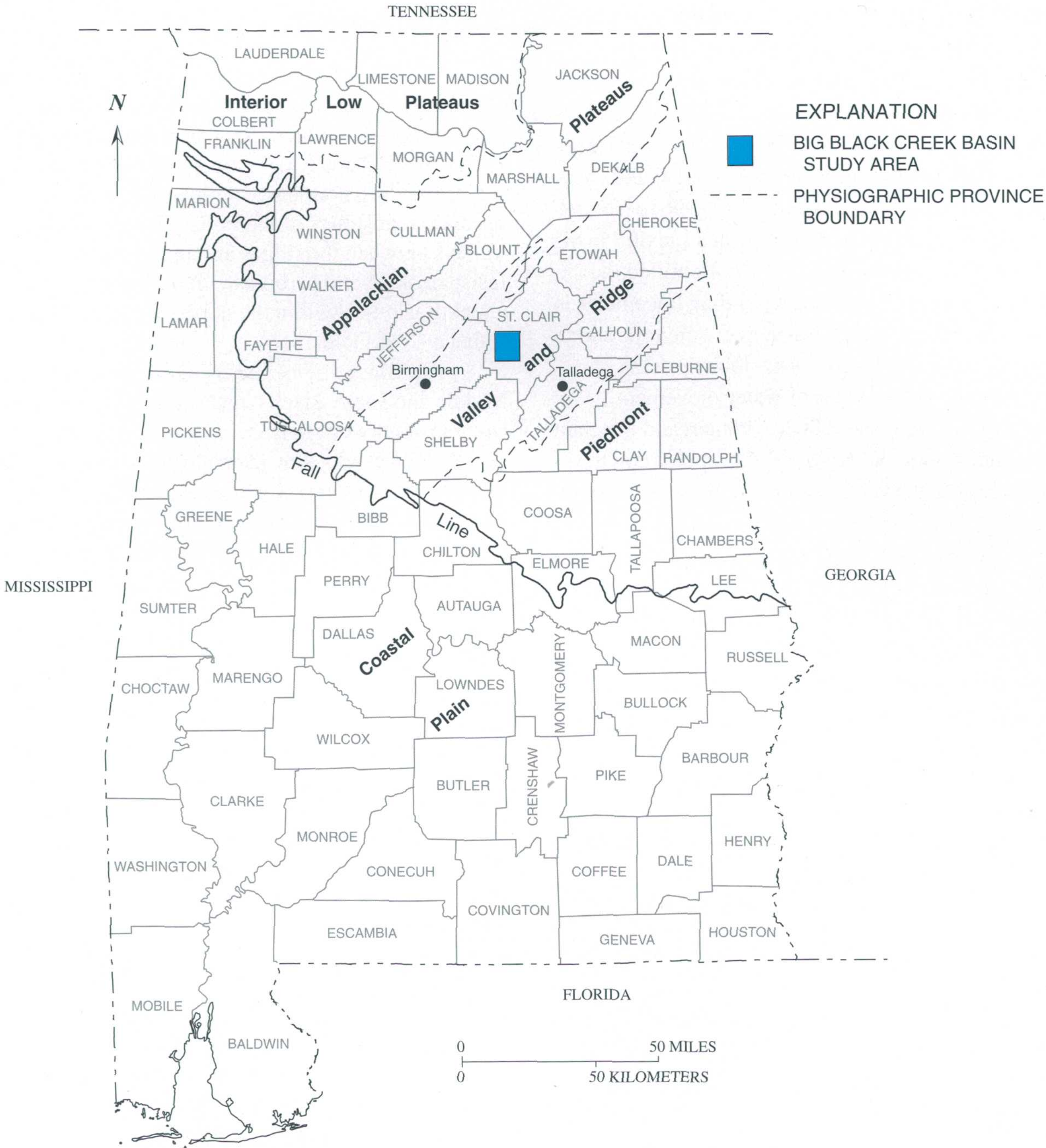

Figure 1. Location of the Big Black Creek Basin study area and physiographic provinces of Alabama (modified from Miller, 1992).

sites. Water samples also were collected from three shallow wells.

Stream-water-quality samples were analyzed for organic compounds, major ions, and trace elements. Bed-sediment samples also were analyzed for organic compounds and trace elements. Ground-water samples were collected from three drive-point wells at two of the stream-water-quality sites and analyzed only for volatile organic compounds (VOCs).

Previous Investigations

The geology and coal resources of the study area have been described by Causey (1963a, b), Culbertson

(1964), Thomas (1972), Planert and Pritchett (1989), Osborne (1995), and Pashin and others (1995). Osborne (1995) and Pashin and others (1995) reported on the structural geology of the Cahaba Coal Field region, which encompasses the Big Black Creek Basin, and presented the structural geology in areal and cross-sectional maps. Gallet and Associates (1996) described the local geology of the Acmar Regional Landfill in the Big Black Creek Basin. Kidd (1979) identified the presence of northwest-southeast trending lineaments in the lower Big Black Creek Basin that were reported to potentially represent faults zones, joint systems, mineralized zones, or zones of water movement. Johnston (1933), Causey (1963a), Planert and Pritchett (1989), and Mooty and Kidd (1996) reported on the hydrogeology and ground-water resources of the study area.

Finkelman and others (1994) compiled existing coal data into the USGS COALQUAL database. The compiled data included coal geochemical data for the Cahaba Coal Field in Alabama. Ground-water-quality samples were collected periodically from selected wells in the ground-water monitoring system at Acmar Regional Landfill and analyzed for inorganic and organic constituents. A report of the analytical results was provided to the ADEM as part of the landfill's permit compliance (Guardian Systems, 1992, 1994, 1995, 1996).

Acknowledgments

The authors thank local landowners who allowed access to measurement sites on their properties. The study would not have been possible without their kind permission.

DESCRIPTION OF THE BIG BLACK CREEK BASIN

The Big Black Creek Basin is in north-central Alabama and has a humid, temperate climate. The mean annual rainfall is 56 inches with March generally being the wettest month (Moody and others, 1985). The basin is primarily forested with minor residential areas present. The Acmar Regional Landfill is the principal commercial activity in the basin.

Physical Setting

The Big Black Creek Basin lies within the Cahaba Ridges district of the Valley and Ridge physiographic province (Sapp and Emplaincourt, 1975). The Cahaba Ridges are a group of parallel linear ridges trending northeast-southwest formed by the resistant sandstones of the Pottsville Formation. Valleys between the ridges are underlain by the less resistant shale and carbonate units. The Big Black Creek Basin lies within the northeastern portion of the Cahaba Coal Field.

Big Black Creek and its major tributaries, Middle and Little Black Creeks, drain 41 square miles (mi^2) in southwestern St. Clair County, Alabama (fig. 2). The creeks flow from northeast to southwest in alignment with the regional geologic structure of the basin. The stream drainage exhibits a rectangular pattern indicating the strong influence of geologic structure.

Geologic Setting

The Big Black Creek Basin is underlain by Paleozoic rocks (fig. 3) that range in age from Early Cambrian to Early Pennsylvanian. The geologic structure of the basin is relatively complex because the rock strata have been extensively faulted and folded. Also, the lithology of the strata changes from dominantly clastic rock (interbedded sandstone, shales, and coal) to carbonate and chert rocks in the east. This variable and complex geology is one of the major natural influences on the hydrology and water chemistry of the ground-water and stream systems.

Ordovician- to Cambrian-aged carbonate and clastic rocks of the Rome Formation, Ketona Dolomite, and Chepultepec and Copper Ridge Dolomites, undifferentiated crop out in thin belts southeast of the Helena Thrust fault between the fault and the Big Black Creek Basin divide (fig. 4). These older rock units are displaced over the younger Pennsylvanian-aged Pottsville Formation by the Helena Thrust fault. The clastic sedimentary rocks of the Pottsville Formation are the dominant lithologic unit in the Big Black Creek Basin. The Pottsville Formation is underlain by the Parkwood Formation and the Bangor Limestone, which do not crop out in the basin.

The resistant sandstone units in the lower part of the Pottsville Formation form ridges that serve as the northwestern hydrologic divide in the Big Black Creek

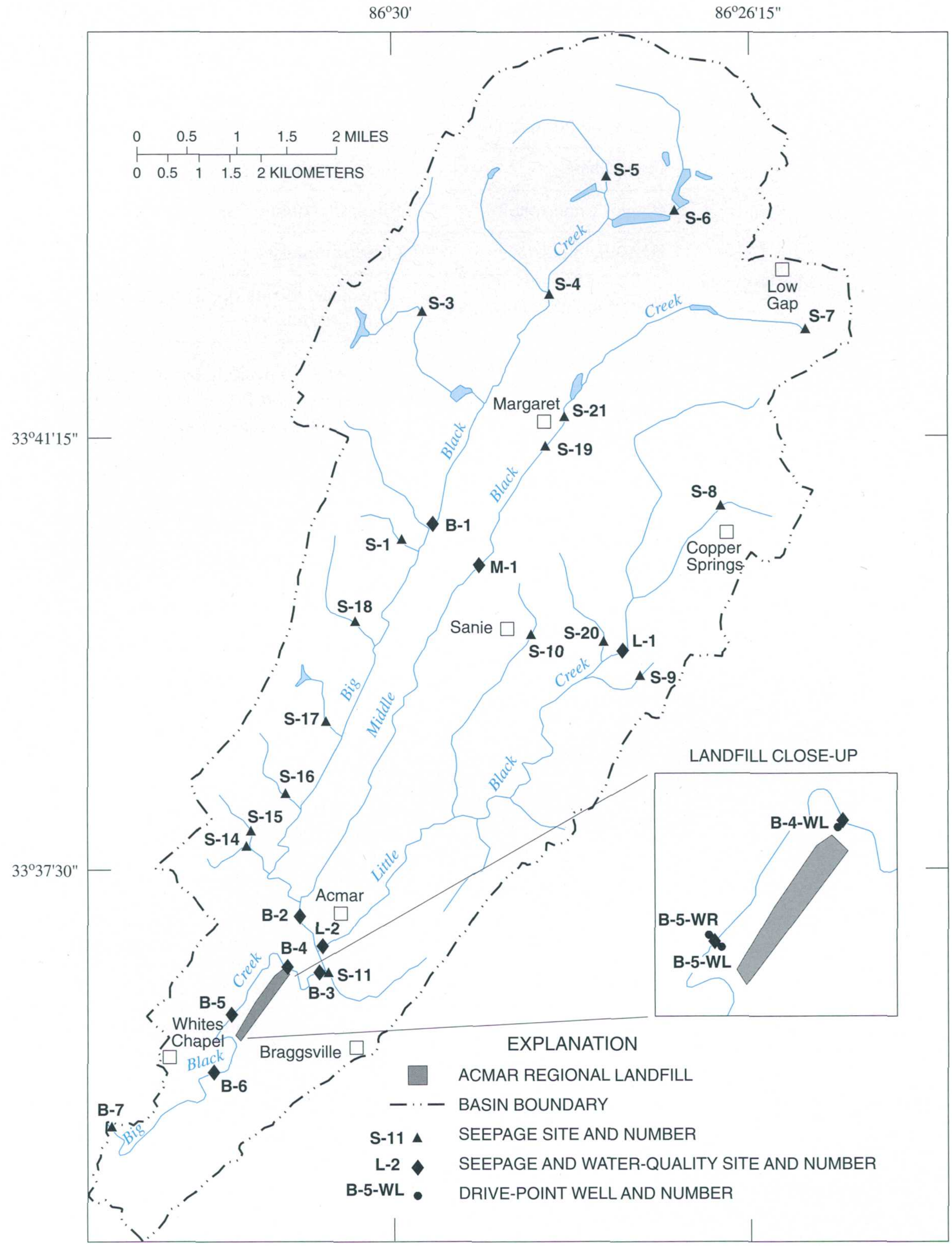

Figure 2. Discharge and water-quality sites in the Big Black Creek Basin.

Era	System	Geologic unit	Lithology
Paleozoic	Pennsylvanian	Pottsville Formation	Sandstone and silty shale, with intervals of coal and underclay.
	Mississippian	Parkwood Formation	Shale, with interbedded lithic sandstone and rare coal.
		Floyd Shale	Shale, with siderite nodules.
		Bangor Limestone	Bioclastic, oolitic limestone with mudstone.
		Hartselle Sandstone	Quartoze sandstone.
		Pride Mountain Formation	Clay-shale, locally occurring thin laminae and interbeds of sandstone.
		Tuscumbia Limestone, Fort Payne Chert, and Maury Formation, undifferentiated	Shale (Maury) overlain by fossiliferous chert with limestone (Fort Payne) and cherty bioclastic limestone (Tuscumbia) at top.
	Devonian	Chattanooga Shale	Shale, highly fissile.
		Frog Mountain Sandstone	Sandstone and chert overlain by red clay.
	Silurian	Red Mountain Formation	Shale with interbedded sandstone and hematite sandstone.
	Ordovician	Little Oak and Lenoir Limestone, undifferentiated	Stylonodular limestone with chert nodules.
		Odenville Limestone	Dolomitic limestone.
		Newala Limestone	Micritic limestone with interbeds of sandy or dolomitic limestone.
		Longview Limestone	Interbedded micritic to sandy limestone and dolomite with chert nodules and beds.
		Chepultepec Dolomite	Dolomite, with abundant chert and intervals of interbedded limestone.
	Cambrian	Copper Ridge Dolomite	Dolomite, with chert algal laminations.
		Ketona Dolomite	Dolomite, no chert.
		Rome Formation	Mudstone, shale, and siltstone with interbeds of sandstone, limestone.

Figure 3. Geologic units in the Cahaba Ridge and Valley districts in Alabama (modified from Osborne, 1995).

Basin. The lower Pottsville Formation unit is composed of a resistant, quartz-rich sandstone interbedded with shale. This unit contains limited coal. The upper part of the Pottsville Formation forms the dominant surface geology over most of the Big Black Creek Basin. The upper unit is characterized by alternating beds of shale and sandstone, with abundant coal seams and associated beds of underclay in cyclic sequences (Pashin and others, 1995). This sandstone unit is composed of quartz and metamorphic rock fragments.

The structure of the northeastern extent of the Cahaba Coal Field and the Big Black Creek Basin is dominated by the Henry Ellen syncline (Osborne,

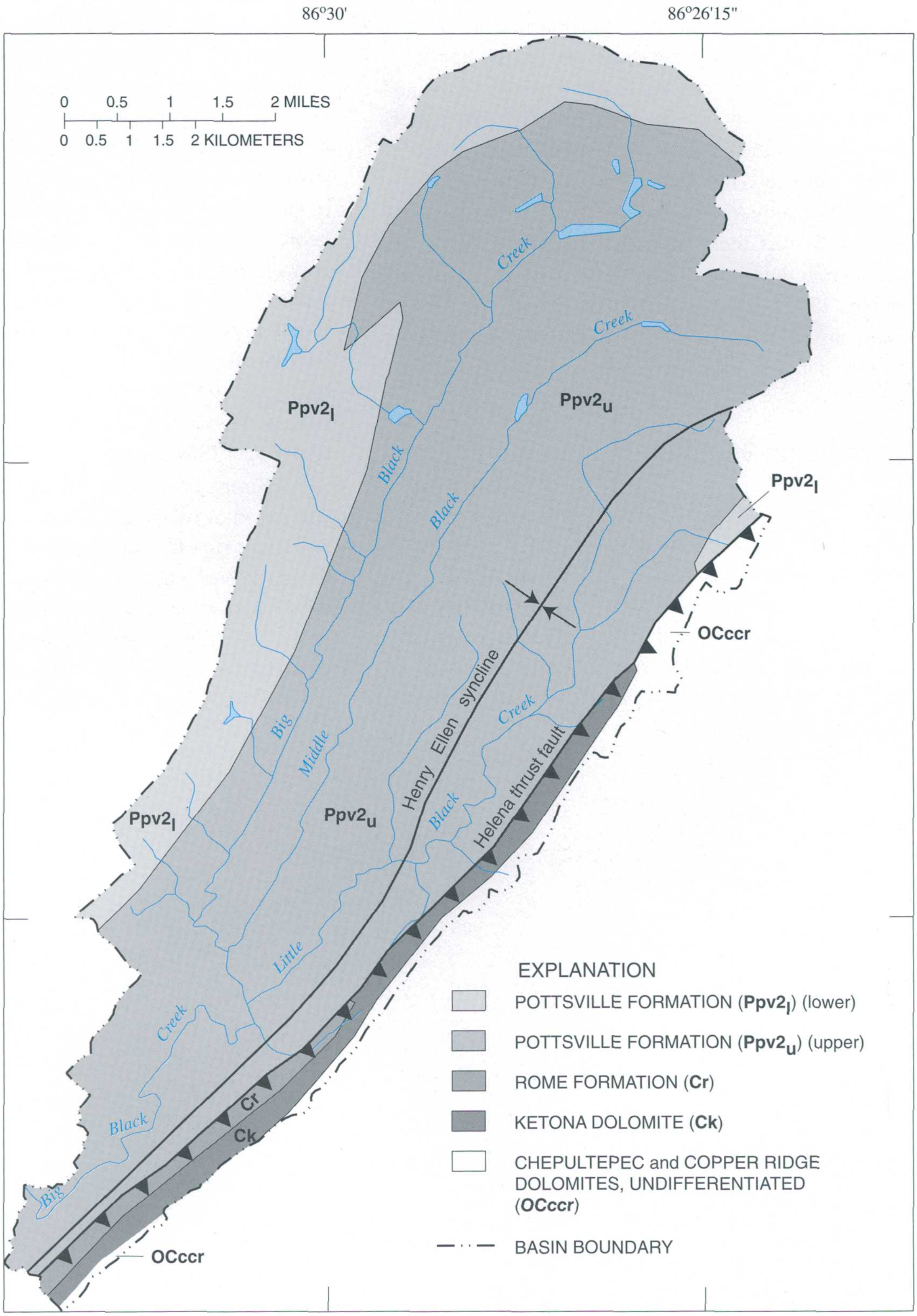

Figure 4. General geology of the Big Black Creek Basin.

1995; Pashin and others, 1995). The Henry Ellen syncline (part of the Cahaba synclinorium) is an asymmetrical, closed fold that has a gently dipping (from 17 to 27 degrees southeast) northwest limb and an overturned, steeply dipping (from 60 to 80 degrees southeast) southeast limb. The axis of the syncline trends northeast-southwest and runs along the southeastern hydrologic boundary in the lower part of the Big Black Creek Basin. In the upper basin, the axis cuts across the Little Black Creek subbasin (Pashin and others, 1995) (fig. 4). The Helena Thrust fault near the southeastern boundary of the Big Black Creek Basin (fig. 4) parallels the axis of the Henry Ellen syncline.

Hydrologic Setting

The stream- and ground-water systems in the Big Black Creek Basin interact dynamically throughout the year. Periods of recharge occur frequently from precipitation associated with frontal passages during the winter and spring and from isolated storms in the summer and fall. Precipitation infiltrates the land surface and percolates downward to the water table and discharges to streams.

Within the Big Black Creek Basin, shallow ground-water flow is assumed to be restricted within the topographic drainage basin boundaries, with ground-water divides being coincident with surface-water divides. Ground water moves either as localized flow in the shallow, porous aquifer system toward Big Black Creek and its tributaries or as more complex flow in the deeper, fracture-conduit aquifer controlled by geologic and manmade structures (fig. 5). Specifically, networks of secondary openings (such as fractures or joints) in the bedrock or abandoned mine shafts that are interconnected with the stream serve as pathways or conduits for ground water. Those geologic and manmade conduits that are not interconnected with the stream may allow ground water to move downgradient to a deeper flow system.

Streamflow in the Big Black Creek Basin is composed of two major components—overland flow, or surface runoff, and base flow. Surface runoff occurs during storms when rainfall flows over the land surface and discharges directly into streams. Base flow is the ground-water discharge component of streamflow. In late summer to early fall, the combined effect of reduced rainfall and maximum evapotranspiration (removal of water by vegetation and evaporation)

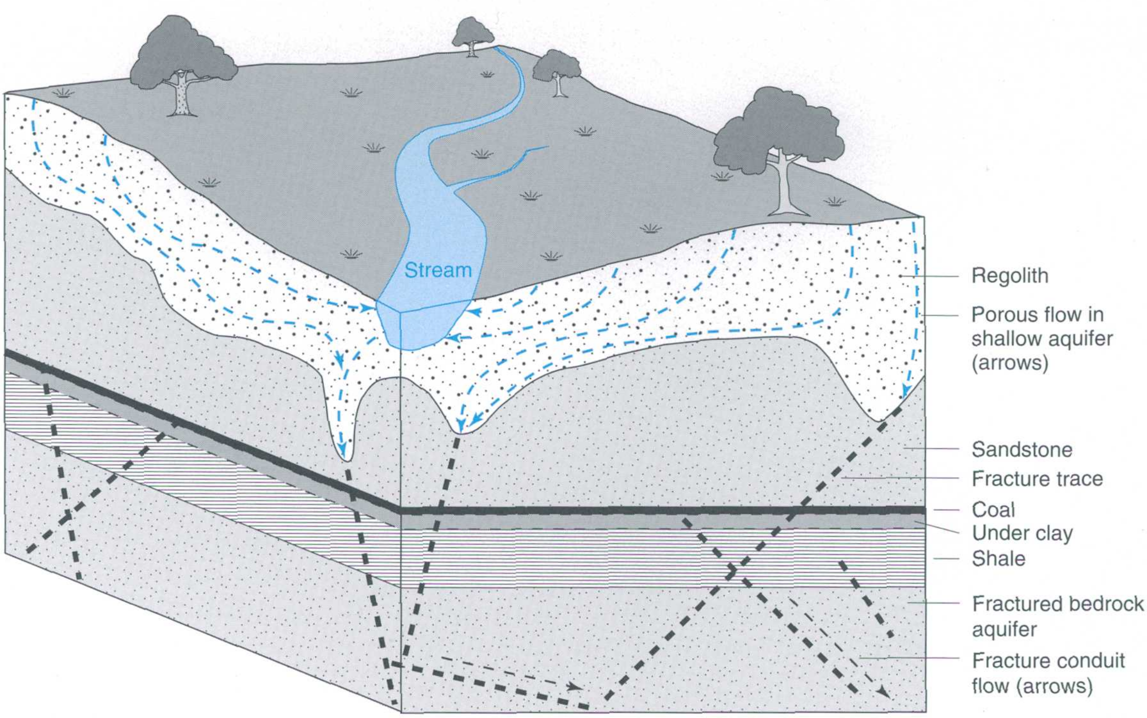

Figure 5. Ground- and surface-water systems in the Big Black Creek Basin.

generally results in all of the streamflow in most streams being from ground-water discharge.

APPROACH AND METHODS OF STUDY

The first part of the hydrologic investigation consisted of a literature review to identify local geologic structures (faults, fractures, and joints), major springs, and abandoned coal mines and to evaluate historical surface- and ground-water-quality data in the Big Black Creek Basin. Based on the data obtained from the literature review, a field reconnaissance of the study area was conducted to select ground-water seepage and water-quality sites. A subset of the water-quality sites with relatively comparable instream habitats was selected for sampling benthic invertebrate communities.

Sampling locations for the water-quality and biological investigations were related to the predominant land-use activities within the basin. Selected sites included representative baseline, coal-influenced, and landfill-influenced sites. This was necessary in order to identify any landfill-derived contamination or impairment in the stream water separately from any contamination derived from the relatively ubiquitous influence of abandoned surface and subsurface coal mining and residential land-use practices in the Big Black Creek Basin. Leachate from landfills and drainage from coal mines and mine-tailing piles can degrade water quality in streams and ground water and impair the health of benthic invertebrate communities. Several commonly used indicators of landfill leachate—acidic pH, toxic metals, elevated trace element, and total dissolved solids concentrations—could not be used exclusively as definitive tracers in the Big Black Creek Basin because toxic metals and trace elements also commonly occur at elevated levels in acidic water draining from coal mines and tailing piles (Wilson and others, 1980). Abandoned coal washes (areas used to separate the organic fraction of coal from the mineral fraction) in the basin can lower the pH of water percolating through them and thereby also release dissolved trace elements, such as arsenic, mercury, and lead, into stream and ground-water systems.

The second part of the investigation involved a synoptic sampling of benthic invertebrate communities in Big Black Creek during July 16–17, 1997. The third and fourth parts of the investigation were accomplished at the same time on August 27, 1997, and consisted of a synoptic sampling event to collect streamflow, water-quality, and bed-sediment data in Big Black Creek and its tributaries during a period of base flow.

The purpose of the streamflow investigation was to measure the discharge, or seepage, of the ground water to the surface-water system so that the potential movement of contaminants in the ground-water system could be evaluated. This part of the investigation identified regions of the basin that exhibited streamflow loss and unusually high streamflow gains. Loss of streamflow in a stream reach could be attributed to stream water returning to the ground-water system in that reach by flowing through naturally occurring geologic structures or through abandoned shafts and adits associated with subsurface coal mining. Conversely, a high gain in streamflow in a stream reach could indicate greater than normal ground-water discharge to the stream in that reach.

The water-quality investigation assessed stream conditions during one low-flow period. Water-quality data were compared to established criteria and standards (Alabama Department of Environmental Management, 1994) to determine if contaminant levels were below or approaching these criteria. Benthic invertebrate community sampling supplemented the water-quality data because it reflected the cumulative effects to which the benthic invertebrates were exposed. Four metrics used by the ADEM were calculated from the benthic invertebrate data to provide information about the health of the benthic invertebrate communities at each site during the period of sampling.

Three analytical comparisons were applied to the water-quality, bed-sediment, and biological data obtained from the synoptic investigations to determine any effects of landfill activities on the water quality in the basin. Data at sites hydrologically downgradient from the landfill were compared to data from baseline sites that are hydrologically upgradient from the landfill to identify the following:

(1) Occurrence of VOCs, such as benzene, toluene, and solvents, in stream water and oil and grease in bed sediment.

(2) Significant change in the stream-water chemistry, including increased trace element concentrations, specific conductivity, biochemical oxygen demand, and nutrient concentration.

(3) Degradation in the benthic invertebrate community structure.

Stream-water chemistry and benthic invertebrate community structure at baseline sites included the influences of coal-mining and/or residential activities in the basin. Comparison of sites downgradient from the landfill with baseline sites identified the presence or absence of "overprinting" of landfill-derived contamination on that derived from other activities in the basin. The absence of such overprinting could suggest that, for the observed hydrologic conditions, either contamination does not migrate off site of the landfill or contamination migrates off site at levels that are significantly less than those already present due to other land-use activities.

Field Reconnaissance

A field reconnaissance was performed on July 2, 1997, to identify any surface expression of local geologic structures in the study area that could influence the hydrology of the basin. No geologic structures were noted that were not earlier identified from the literature review. During this reconnaissance, nine sites were selected for synoptic water-quality and bed-sediment sampling based on dominant land use, stream access, and channel conditions. Four of the nine water-quality sites were selected for biological sampling based on dominant land use and comparable habitats. A second reconnaissance of the study area was made on August 4, 1997, to identify streamflow measurement sites and to construct measuring sections to assure stable streamflow conditions. Twenty-eight sites within the Big Black Creek Basin were selected for synoptic streamflow measurements (fig. 2; table 1).

No major springs upgradient from the coal-mining and landfill activities could be sampled to define baseline conditions in ground water for comparison to potentially impacted sites in the basin. Thus, shallow drive-point wells were installed to sample for VOCs in the shallow ground water discharging to the stream near the landfill. The presence of manmade VOCs in stream water or in ground water discharging to the stream would indicate landfill-derived contamination rather than surface and subsurface coal-mine drainage. Both stream water and ground water were sampled because of the common loss of VOCs in stream water as a result of volatilization, especially when VOCs are derived from low-level sources.

Stainless steel drive-point wells were installed in the streambank at two water-quality surface-water sites adjacent to the landfill. The drive points were set at a depth of about 4 feet (ft). The drive-point wells were considered downgradient from the landfill, except for one well that was on the opposite side of the stream from the landfill and was used as a baseline site.

Streamflow Investigation

A graphic recorder was installed at site B-6 on Big Black Creek and operated during August 18–28, 1997, to provide a continuous record of the water level in the stream. The synoptic measurement of stream discharge at the 28 sites was made on August 27, 1997, during a period of base flow. Stream discharge and water-quality field properties of water temperature, specific conductivity, and pH were measured at each site. All pH and conductivity meters were calibrated with known standards prior to sampling. Stream discharges were calculated from measurements of width, depth, and velocity by using a pygmy current meter or by using a float as described in Buchanan and Somers (1969) where shallow stream depths prevented the use of a meter. Net gains and yields were computed for the stream reaches from the data collected during the synoptic investigation. These data also were used in the interpretation of the water-quality data collected in

Table 1. Description of data-collection sites in the Big Black Creek Basin, Alabama

[X for samples collected; blank for no samples collected; mi^2, square mile]

Site no. (fig. 2)	Station no.[a]	Station name	Drainage area (mi^2)	Data collected: Biological	Water quality	Bed sediment	Streamflow
S-5	02423165	Big Black Creek at Simmons Mountain Road near Margaret	1.31				X
S-6	02423166	Unnamed tributary to Big Black Creek at Simmons Mountain Road near Margaret	2.27				X
S-4	02423167	Big Black Creek near Margaret	6.64				X

Table 1. Description of data-collection sites in the Big Black Creek Basin, Alabama—Continued

[X for samples collected; blank for no samples collected; mi^2, square mile]

Site no. (fig. 2)	Station no.[a]	Station name	Drainage area (mi^2)	Data collected			
				Bio-logical	Water quality	Bed sediment	Stream-flow
S-3	02423168	Unnamed tributary 1 to Big Black Creek near Margaret	1.23				X
B-1	02423170	Big Black Creek near Margaret	10.8		X		X
S-1	02423171	Unnamed tributary 3 to Big Black Creek near Margaret	.47				X
S-18	02423172	Unnamed tributary 4 to Big Black Creek near Margaret	.47				X
S-17	02423173	Unnamed tributary 5 to Big Black Creek near Margaret	.50				X
S-16	02423174	Unnamed tributary 1 to Big Black Creek near Acmar	.39				X
S-15	02423175	Unnamed tributary 2 to Big Black Creek near Acmar	.24				X
S-14	02423176	Unnamed tributary to unnamed tributary 2 to Big Black Creek near Acmar	.36				X
S-7	02423179	Middle Black Creek near Low Gap	.19				X
S-21	0242317940	Middle Black Creek above Margaret	3.71				X
S-19	0242317950	Middle Black Creek at Margaret	3.92				X
M-1	02423180	Middle Black Creek near Sanie	4.84		X		X
B-2	02423183	Big Black Creek near Acmar	23.3	X	X	X	X
S-8	0242318650	Unnamed tributary to Little Black Creek at Copper Springs	.73				X
L-1	02423184	Little Black Creek near Sanie	5.38	X	X	X	X
S-20	0242318425	Unnamed tributary 1 to Little Black Creek near Sanie	.51				X
S-9	0242318450	Unnamed tributary 2 to Little Black Creek near Sanie	.19				[b]
S-10	0242318475	Unnamed tributary 3 to Little Black Creek near Sanie	.38				[b]
L-2	02423185	Little Black Creek near Acmar	12.2		X	X	X
S-11	0242318675	Unnamed tributary to Big Black Creek near Acmar	1.35				X
B-3	02423187	Big Black Creek near Braggsville	37.1		X	X	X
B-4	02423188	Big Black Creek above Whites Chapel	37.2		X	X	X
B-4-WL	333640 0863106	Well Point at Big Black Creek above Whites Chapel, left bank (downgradient from landfill)	—		X		
B-5	02423189	Big Black Creek near Whites Chapel	37.9	X	X	X	X
B-5-WL	333616 0863143	Well Point at Big Black Creek near Whites Chapel, left bank (downgradient from landfill)	—		X		
B-5-WR	333616 0863145	Well Point at Big Black Creek near Whites Chapel, right bank (upgradient from landfill)	—		X		
B-6	02423190	Big Black Creek near Leeds	39.3	X	X	X	X
B-7	02423200	Mouth of Big Black Creek	41.1				X

[a]Station number is assigned by the USGS and is based on geographic location. The "downstream order number" system is used for streamflow sites, and the "latitude-longitude"system is used for well sites.

[b]Sites were dry at the time of sampling.

the basin and in the computation of instantaneous trace-element loads.

Water-Quality Investigation

Synoptic stream-water-quality samples were collected at nine sites (B-1, M-1, B-2, L-1, L-2, B-3, B-4, B-5, and B-6) on Big Black Creek and its tributaries on August 27, 1997, during a period of base flow (table 1). Sites B-1, M-1, B-2, L-1, L-2, and B-3 were considered baseline sites that represented water-quality conditions across the range of land use in the basin, including residential land use (site M-1) and coal-mine drainage (sites B-1, B-2, B-3, M-1, and L-2). Only one site was not directly affected by coal-mine activity (site L-1). Sites B-4, B-5, and B-6 were downgradient from the Acmar Regional Landfill and considered potentially influenced by ground-water discharge from the landfill during this sampling event. Site B-5 also is located immediately downstream from an abandoned coal wash.

Measurements of stream discharge, pH, dissolved-oxygen concentration, water temperature, specific conductance, and alkalinity were made in the field at the time of sampling. Water samples collected in Big Black Creek were analyzed for indicator constituents that are associated with landfill leachate according to the U.S. Environmental Protection Agency (USEPA) (1977) and the Intergovernmental Task Force on Monitoring Water Quality (1995). Water samples were analyzed for color, major ions (sodium, potassium, calcium, magnesium, chloride, sulfate, and fluoride), VOCs (USEPA method 524.2), oil and grease (USEPA method 1664), total phenols, total organic carbon, chemical oxygen demand, total recoverable trace elements (aluminum, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, and zinc), and 5-day biochemical oxygen demand. The stream-water samples were collected according to USGS protocols (Horowitz and others, 1994; Shelton, 1994; Shelton and Capel, 1994) and USEPA standard operating procedures for environmental investigations (U.S. Environmental Protection Agency, 1996). The collected samples were sent to the USGS National Water Quality Laboratory in Denver, Colo., for analysis.

Ground-water samples were collected from three shallow drive-point wells (B-4-WR, B-5-WL, and B-5-WR) at two stream sites (B-4 and B-5) and analyzed for VOCs. The metal of the well casings and screens precluded analysis of the samples for trace elements. Previous ground-water sampling from the on-site monitoring system by the Acmar Regional Landfill detected several VOCs in ground water at the landfill (Guardian Systems, 1992, 1994, 1995). The drive-point wells were used to determine if any previously detected VOCs had migrated off site during base-flow conditions. The drive-point wells were purged a total of three well volumes by using a peristaltic pump for about 16 hours prior to sampling. The samples were collected by lowering the 40-milliliter (mL) septum vial into the drive-point well by using a methanol-rinsed steel rod.

Bed-sediment samples were collected at seven of the nine surface-water sites (B-2, L-1, L-2, B-3, B-4, B-5, and B-6). Bed-sediment samples were collected according to USGS protocols (Horowitz and others, 1994; Shelton, 1994; Shelton and Capel, 1994) and USEPA standard operating procedures for environmental investigations (U.S. Environmental Protection Agency, 1996). Bed-sediment samples were analyzed for arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, zinc, and oil and grease (USEPA method 418.1) and scanned for semivolatile organic compounds. The oil and grease analysis was performed by Quanterra Environmental Services Laboratory in Arvada, Colo. Trace-element analysis and semivolatile organic compound scans were conducted by the USGS National Water Quality Laboratory in Denver, Colo. Semivolatile organic compound scans, rather than analyses of specific compounds, were used to determine the presence of these compounds in the sample to reduce the analytical cost. Petrographic analysis of duplicate sediment samples at selected sites was used to estimate the percentage coal composition of the sediment.

Benthic Invertebrate Community Sampling

Benthic invertebrates are bottom-dwelling aquatic animals, such as insect larvae, mollusks, and worms, that lack backbones. The presence, absence, or relative abundance of various types of benthic invertebrates in a stream can be used to make a general assessment of the stream's water quality. Sampling of the benthic invertebrate communities is a valuable supplement to chemical-based sampling because the biota respond to the cumulative effects of certain chemicals to which they are exposed (Rosenberg and Resh, 1993).

Benthic invertebrate community samples were collected as a part of the water-quality assessment study of the Big Black Creek Basin. Sampling was conducted at one site on Little Black Creek (L-1) and at three sites on Big Black Creek (B-2, B-5, B-6) during July 16–17, 1997 (table 1). Site L-1 served as a reference site free from the influences of coal mining and landfill activities. If degradation of the biological community was indicated by the sites on Big Black Creek, the reference site on Little Black Creek would provide a means to assess the severity of the degradation. The Big Black Creek sites were chosen to represent conditions (1) upstream from the landfill (B-2), (2) adjacent to the landfill (B-5), and (3) downstream from the landfill (B-6). All of the sites on Big Black Creek were potentially influenced by coal-mining activities, particularly site B-5, which is directly downstream from an abandoned coal wash. If contamination from the landfill was reaching the stream, the benthic invertebrate communities downgradient from the landfill at sites B-5 and B-6 could show signs of degradation.

A combination of the ADEM Standard Operating Procedures (Alabama Department of Environmental Management, 1996) and USGS (Cuffney and others, 1993) protocols was used to sample the four stream reaches. Each stream reach was inspected from the bank to determine the types of instream habitat that were available for sampling. The six possible types of habitat included riffle, coarse particulate organic matter (CPOM), log/rock, root/bank, sand, and macrophyte as described in Section 6.6 of the ADEM Standard Operating Procedures Manual (Alabama Department of Environmental Management, 1996). Three of the six instream habitat types were sampled separately at all four sites: (1) riffle, (2) log/rock, and (3) root/bank. Sample material from all habitats was collected using 425-micron mesh aquatic nets. Three subsamples for each habitat were collected and composited at each stream reach.

Riffle samples were collected by placing an aquatic net downstream from a square area defined by the net's width. Large rocks that were in the defined area were collected, cleaned off by hand, and then scrubbed with a brush. Remaining rocks and sediment in the sample area were disturbed by stirring with the brush handle, followed by about 30 seconds of kicking and shuffling the substrate. Log/rock samples were collected from submerged logs or rocks. The log or rock was carefully picked up and the net placed quickly beneath it. The log or rock was washed by hand and then with a brush to dislodge surface organisms. Bark of branches was broken off and inspected visually for organisms burrowing underneath. Root/bank samples were collected by placing the aquatic net underneath and then around overhanging roots that were immersed in water at the stream edge. The roots were agitated by quickly moving the net back and forth.

Processing of samples was the same for all sites and habitat types. Three samples from each habitat were transferred to and composited in a white 5-gallon bucket. Elutriation of the composited sample material was accomplished by stirring until the sediments were in suspension, and then pouring the liquid portion through a 425-micron mesh sieve. The elutriation process was repeated at least three times. Material remaining in the bucket was inspected for heavier invertebrates such as clams or mussels, which were added to the material in the sieve. The volume of material collected in the sieve was reduced as much as possible by discarding rocks, sticks, and other large plant material after inspecting them for clinging invertebrates. Two different sizes (500 mL and 1 liter [L]) of polyethylene preservation bottles were used; the appropriate size for use was determined by the amount of material left for preservation. Collected material was carefully transferred to the sample bottle and preserved with a 10-percent formalin solution.

All samples were shipped to Pennington & Associates, Inc., of Cookeville, Tenn., for processing and identification of the invertebrates. Benthic invertebrates were identified to the lowest taxonomic level possible. Types and number of invertebrates in each sample were determined.

Four metrics used by the ADEM were calculated from the data. These metrics were taxa richness, EPT index, chironomid taxa richness, and biotic index (BI). For the metric calculations, separate habitat-type data at each site were combined. Each metric provided information about the health of the benthic invertebrate communities at each site during the period of sampling. A brief description of each of the metrics follows.

Taxa richness is the number of distinct taxa found at a site. Taxa richness is typically expected to be lower at contaminated sites because intolerant species cannot live in the altered environment.

Some taxa are known to be generally more intolerant to organic enrichment and/or trace elements than others. For example, the Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are major groups that are generally thought to be intolerant and are commonly referred to as EPT taxa. The EPT index used in this report is the number of distinct genera in the sample from the EPT orders.

The Chironomidae (midges) are another major group in benthic invertebrate communities. They are considered to be more tolerant of contamination effects than the EPT taxa. Chironomid taxa richness presented in this report is the number of distinct chironomid genera found in the sample. According to the ADEM, "Good biotic condition is reflected in communities having a fairly even distribution among all four major groups and with substantial representation in the sensitive groups Ephemeroptera, Plecoptera, and Trichoptera," (Alabama Department of Environmental Management, 1996).

The BI is calculated from tolerance values for specific organisms using the formula $BI = \Sigma (x_i t_i) \div n$, where x_i = number of individuals within a taxa, t_i = tolerance value of a taxa, and n = total number of organisms in the sample with tolerance values, as described in Section 8.6.1.1 of the ADEM's Standard Operating Procedures (Alabama Department of Environmental Management, 1996). Tolerance values are on a scale of 0 to 10, with 10 being most tolerant to general pollution. Tolerance values used in this report are from Appendix X-1 of the ADEM's Standard Operating Procedures Manual (Alabama Department of Environmental Management, 1996). BI values increase as the ratio of tolerant to intolerant species increases. High BI values imply that some change in water quality has occurred that discourages intolerant species.

The existence and severity of benthic invertebrate community impairment at a site is determined by comparing it to the community at a site known to have little or no water-quality impairment and similar in geographic and geologic aspects to the site in question. The ADEM has established a benthic invertebrate sampling site (TCT-5), which meets the requirements for a reference site, on Talladega Creek in Talladega County (Highway 77 bridge south of Talladega, T. 19 S., R. 6 E., sec. 17). Data from site TCT-5 were available from three sampling runs conducted by the ADEM in April 1990, June 1993, and May 1995. For comparison with the Big Black Creek Basin sites, metrics from site TCT-5 were calculated using only data from the riffle, log/rock, and root/bank habitats.

The ADEM also has developed criteria for metrics for Appalachian streams in North Alabama (L. Houston, Alabama Department of Environmental Management, written commun., Nov. 7, 1997). These criteria are based on composites of all six possible instream habitats.

STREAMFLOW, WATER-QUALITY, AND BIOLOGICAL CONDITIONS

This section presents the results of synoptic sampling events for streamflow conditions, water and bed-sediment quality, and benthic invertebrate communities. Observations and discussions about the data are related to potential effects of mine drainage or landfill leachate seepage into Big Black Creek and represent the prevailing low-flow conditions during a one-time sampling effort. Additional data are required for other flow conditions and for other seasonal variables in order to have a more complete picture of the biologic and hydrologic regime of the Big Black Creek Basin.

Data from these investigations are summarized in tables, figures, and appendixes. Results of the benthic invertebrate community sampling are listed in appendix 1. A list of the VOCs analyzed in the water-column samples and their detection limits are provided in appendix 2.

Streamflow

Continuous surface-water levels were measured at site B-6. The recorded water-level data indicated a steady recession during the period of record (August 18–28, 1997), during which the water level fluctuated less than 0.2 ft. On the date of the synoptic sampling, the water level at site B-6 varied less than 0.1 ft. These data show that base-flow conditions existed throughout the Big Black Creek Basin during the sampling period.

Data-collection efforts for the streamflow investigation began on August 27, 1997, at 28 sites that were selected and prepared during the second field reconnaissance. Stream discharge and water-quality field properties of water temperature, specific conductivity, and pH were measured at 26 of the 28 selected sites (table 2). Site B-7, located at the mouth of Big Black Creek approximately 500 ft above the confluence of the Cahaba River, was measured on August 28, 1997, because of logistic- and time-related constraints.

Table 2. Stream discharge and water-quality field properties at synoptic sites in the Big Black Creek Basin, August 27, 1997

[mi^2, square mile; ft^3/s, cubic foot per second; $[ft^3/s]/mi^2$, cubic foot per second per square mile; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; °C, degrees Celsius; —, no data]

Site no. (fig. 2)	Station no.[a]	Station name	Drainage area (mi^2)	Stream discharge (ft^3/s)	Stream yield ($[ft^3/s]/mi^2$)	Water-quality field properties			
						pH	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Water temperature (°C)
S-5	02423165	Big Black Creek at Simmons Mountain Road near Margaret	1.31	0.067	0.051	7.2	40	—	26.0
S-6	02423166	Unnamed tributary to Big Black Creek at Simmons Mountain Road near Margaret	2.27	.022	.010	7.1	40	—	24.0
S-4	02423167	Big Black Creek near Margaret	6.64	.24	.036	7.3	67	—	22.0
S-3	02423168	Unnamed tributary 1 to Big Black Creek near Margaret	1.23	.007	.006	6.9	99	—	22.0
B-1	02423170	Big Black Creek near Margaret	10.8	.32	.030	7.1	59	6.5	24.0
S-1	02423171	Unnamed tributary 3 to Big Black Creek near Margaret	.47	.001	.002	6.6	54	—	23.5
S-18	02423172	Unnamed tributary 4 to Big Black Creek near Margaret	.47	.004	.009	7.2	45	—	20.5
S-17	02423173	Unnamed tributary 5 to Big Black Creek near Margaret	.50	.26	.52	6.8	22	—	23.0
S-16	02423174	Unnamed tributary 1 to Big Black Creek near Acmar	.39	.010	.026	6.8	30	—	20.5
S-15	02423175	Unnamed tributary 2 to Big Black Creek near Acmar	.24	.013	.054	6.7	21	—	21.0
S-14	02423176	Unnamed tributary to unnamed tributary 2 to Big Black Creek near Acmar	.36	.007	.02	6.4	60	—	20.5
S-7	02423179	Middle Black Creek near Low Gap	.19	.003	.02	6.7	114	—	26.0
S-21	0242317940	Middle Black Creek above Margaret	3.71	.098	.026	7.0	182	—	—
S-19	0242317950	Middle Black Creek at Margaret	3.92	.051	.013	6.8	171	—	24.5
M-1	02423180	Middle Black Creek near Sanie	4.84	.52	.107	7.6	710	8.3	21.5
B-2	02423183	Big Black Creek near Acmar	23.3	1.8	.077	7.4	367	5.6	21.0
S-8	0242318650	Unnamed tributary to Little Black Creek at Copper Springs	.73	.021	.029	7.7	155	—	20.0
L-1	02423184	Little Black Creek near Sanie	5.38	.096	.018	8.1	235	8.6	24.5
S-20	0242318425	Unnamed tributary 1 to Little Black Creek near Sanie	.51	.005	.01	6.9	64	—	30.0
S-9	0242318450	Unnamed tributary 2 to Little Black Creek near Sanie	.19	0	0	—	—	—	—

Table 2. Stream discharge and water-quality field properties at synoptic sites in the Big Black Creek Basin, August 27, 1997—Continued

[mi^2, square mile; ft^3/s, cubic foot per second; $[ft^3/s]/mi^2$, cubic foot per second per square mile; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; °C, degrees Celsius; —, no data]

Site no. (fig. 2)	Station no.[a]	Station name	Drainage area (mi^2)	Stream discharge (ft^3/s)	Stream yield ($[ft^3/s]/mi^2$)	Water-quality field properties			
						pH	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Water temperature (°C)
S-10	0242318475	Unnamed tributary 3 to Little Black Creek near Sanie	0.38	0	0	—	—	—	—
L-2	02423185	Little Black Creek near Acmar	12.2	.98	.080	7.2	178	7.6	20.5
S-11	0242318675	Unnamed tributary to Big Black Creek near Acmar	1.35	.25	.19	7.5	289	—	25.0
B-3	02423187	Big Black Creek near Braggsville	37.1	2.7	.073	7.4	271	6.4	21.0
B-4	02423188	Big Black Creek above Whites Chapel	37.2	2.9	.078	7.3	266	6.7	21.5
B-4-WL	—	Well Point at Big Black Creek above Whites Chapel, left bank (down-gradient from landfill)	—	—	—	—	—	—	—
B-5	02423189	Big Black Creek near Whites Chapel	37.9	3.3	.087	6.8	357	7.2	23.0
B-5-WL	—	Well Point at Big Black Creek near Whites Chapel, left bank (down-gradient from landfill)	—	—	—	—	227	.4	21.0
B-5-WR	—	Well Point at Big Black Creek near Whites Chapel, right bank (up-gradient from landfill)	—	—	—	—	204	.2	21.5
B-6	02423190	Big Black Creek near Leeds	39.3	4.1	.10	7.2	332	7.3	22.0
B-7	02423200	Mouth of Big Black Creek	41.1	4.4	.11	7.4	326	—	—

[a]USGS downstream order number.

Synoptic discharge measurements ranged from 0.001 cubic foot per second (ft^3/s) at site S-1 to 4.4 ft^3/s at the mouth of Big Black Creek (B-7) (fig. 6; table 2). Sites S-9 and S-10, located on two second-order tributaries, were dry. The stream yields were generally less than 0.10 cubic foot per second per square mile ($[ft^3/s]/mi^2$) at the second-order tributary sites and less than 0.25 $(ft^3/s)/mi^2$ at the main stem sites.

The computed net gains and yields (table 3) identified areas in the Big Black Creek Basin that exhibited channel gains or losses in streamflow (fig. 7). Two areas of channel loss were identified—between sites S-21 and S-19 on Middle Black Creek and between the confluence of Little Black Creek with Big Black Creek (B-2) and site B-3, located upstream and upgradient from the Acmar Regional Landfill. The sum of streamflow at sites S-11 and L-2 and the net gain in streamflow at site B-2 was greater than the streamflow measured at site B-3. The net gain in streamflow at site S-21 also was greater than the streamflow at downstream site S-19 on Middle Black Creek. Losses in streamflow between these sites may be a result of surface water returning to the ground-water system by flowing through naturally occurring geologic structures or through improperly abandoned shafts and adits associated with subsurface coal mining. Immediately downstream from these reaches of streamflow loss were reaches of greater than normal streamflow gain, suggesting a greater contribution from ground water in these reaches.

Net yields in streamflow between sites B-3 and B-4, B-4 and B-5, B-5 and B-6, and sites S-19 and M-1 indicated drainage areas of significantly higher ground-water discharge (1.3, 0.57, 0.57, and 0.51 $(ft^3/s)/mi^2$, respectively) compared to the rest of the basin (-1.3 to 0.17 $(ft^3/s)/mi^2$) (table 3). Further review of historical coal-mining activities (Gallet and Associates, 1996) and USGS topographic maps (Odenville 7.5-minute quadrangle, photorevised 1972) identified the presence of coal mine shafts in the part of the basin containing these losing and high-gaining stream reaches.

Stream reaches downgradient from the landfill have higher ground-water discharge to the stream than the rest of the basin. If significant leakage of leachate from the landfill had occurred during the measurement period, the distribution of ground-water discharge suggests that the leachate would travel relatively short

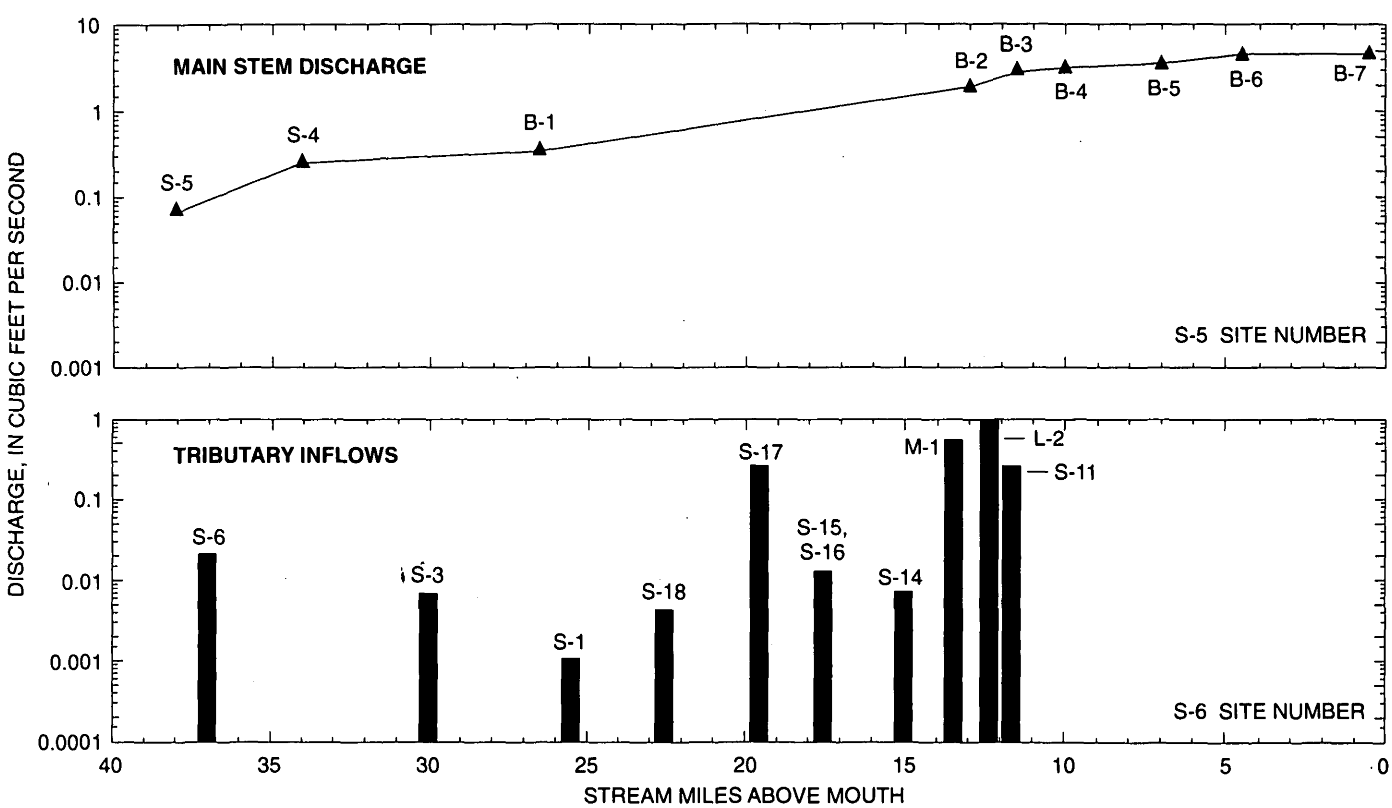

Figure 6. Main stem discharge and tributary inflow to Big Black Creek on August 27, 1997.

Table 3. Net gain and yield in stream discharge at selected surface-water sites in the Big Black Creek Basin, August 27–28, 1997

[mi^2, square mile; ft^3/s, cubic foot per second; $[ft^3/s]/mi^2$, cubic foot per second per square mile; —, not applicable]

Site no. (fig. 2)	Station name	Drainage area (mi^2)	Discharge (ft^3/s)	Intermediate drainage area[a] (mi^2)	Net gain in discharge[b] (ft^3/s)	Net yield in discharge[c] ($[ft^3/s]/mi^2$)
	Little Black Creek subbasin					
S-8	Unnamed tributary to Little Black Creek at Copper Springs	0.73	0.021	—	—	—
L-1	Little Black Creek near Sanie	5.38	.096	4.65	0.075	0.016
S-20	Unnamed tributary 1 to Little Black Creek near Sanie	.51	.005	—	—	—
S-9	Unnamed tributary 2 to Little Black Creek near Sanie	.19	0	—	—	—
S-10	Unnamed tributary 3 to Little Black Creek near Sanie	.38	0	—	—	—
L-2	Little Black Creek near Acmar	12.2	.98	5.74	.88	.15
	Middle Black Creek subbasin					
S-7	Middle Black Creek near Low Gap	0.19	0.003	—	—	—
S-21	Middle Black Creek above Margaret	3.71	.098	3.52	0.095	0.027
S-19	Middle Black Creek at Margaret	3.92	.051	.21	-.047	-.22
M-1	Middle Black Creek near Sanie	4.84	.52	.92	.47	.51
	Big Black Creek Basin					
S-5	Big Black Creek at Simmons Mountain Road near Margaret	1.31	0.067	—	—	—
S-6	Unnamed tributary to Big Black Creek at Simmons Mountain Road near Margaret	2.27	.022	—	—	—
S-4	Big Black Creek near Margaret	6.64	.24	3.06	0.15	0.049
S-3	Unnamed tributary 1 to Big Black Creek near Margaret	1.23	.007	—	—	—
B-1	Big Black Creek near Margaret	10.8	.32	2.93	.073	.025
S-1	Unnamed tributary 3 to Big Black Creek near Margaret	.47	.001	—	—	—
S-18	Unnamed tributary 4 to Big Black Creek near Margaret	.47	.004	—	—	—
S-17	Unnamed tributary 5 to Big Black Creek near Margaret	.50	.26	—	—	—
S-16	Unnamed tributary 1 to Big Black Creek near Acmar	.39	.010	—	—	—
S-15	Unnamed tributary 2 to Big Black Creek near Acmar	.24	.013	—	—	—
S-14	Unnamed tributary to unnamed tributary 2 to Big Black Creek near Acmar	.36	.007	—	—	—
B-2	Big Black Creek near Acmar	23.3	1.8	10.1	1.2	.12
L-2	Little Black Creek near Acmar	12.2	.98	—	—	—
S-11	Unnamed tributary to Big Black Creek near Acmar	1.35	.25	—	—	—
B-3	Big Black Creek near Braggsville	37.1	2.7	.25	-.33	-1.3
B-4	Big Black Creek above Whites Chapel	37.2	2.9	.10	.20	1.3
B-5	Big Black Creek near Whites Chapel	37.9	3.3	.70	.40	.57
B-6	Big Black Creek near Leeds	39.3	4.1	1.4	.80	.57
B-7	Mouth of Big Black Creek	41.1	4.4	1.80	.30	.17

[a]Computed by subtracting the drainage area of immediately upstream reach and any tributaries from the drainage area at the site.
[b]Computed by subtracting the cumulative discharge at immediately upstream sites and any tributary sites from the discharge at the site.
[c]Computed by dividing the net gain in discharge at the site by the intermediate drainage area.

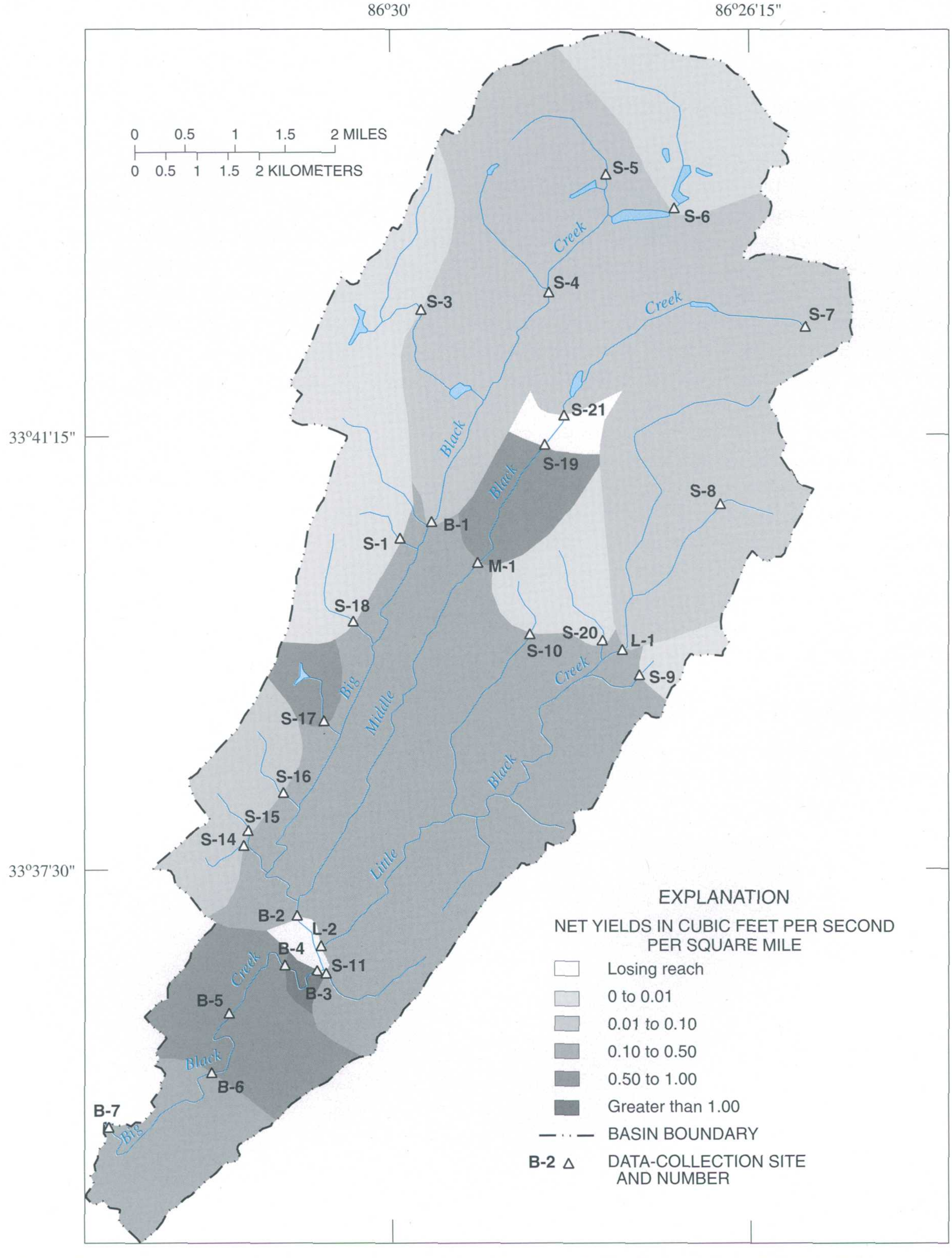

Figure 7. Net yields of selected channel reaches in the Big Black Creek Basin, August 27–28, 1997.

distances before resurfacing as ground-water discharge to the stream.

Water Quality and Bed Sediment

Data collection for the synoptic water-quality investigation, which included 9 water-column sites, 7 bed-sediment sampling sites, and 3 ground-water sampling sites, began on August 27, 1997, in the Big Black Creek Basin. The data obtained from this investigation are categorized according to field water-quality properties, major ions, organic compounds, and trace elements (table 4). Water-column samples were analyzed for major ions, selected trace elements, VOCs, and other synthetic organic compounds (phenols, oil and grease). Bed-sediment samples were collected from seven of the nine sites, analyzed only for oil and grease and selected trace elements, and scanned for semivolatile organic compounds. Water samples collected from the three drive-point wells were analyzed only for VOCs. The major-ion and field water-quality data were used in a geochemical speciation computer program to characterize the equilibrium geochemistry of the stream water.

Field Water-Quality Properties

Specific conductance is an indicator of dissolved-solids concentrations in water. Specific conductance ranged from about 22 microsiemens per centimeter (µS/cm) at site S-17 to 710 µS/cm at site M-1 within the Big Black Creek Basin (table 2). In general, the second- and third-order tributaries (drainage areas of less than 1 mi^2) had specific conductance values of less than 100 µS/cm; hence, the stream water contained very low dissolved solids. In the lower part of the basin, however, stream water contained larger amounts of dissolved solids with specific conductance values ranging from 266 µS/cm at site B-4 to 357 µS/cm at site B-5, which is immediately downstream from an abandoned coal wash.

Measurements of pH were taken at 26 sites (table 2) and ranged from 6.4 (site S-14) to 8.1 (site L-1) within the basin. Except for site L-1, pH differences between sites in the Big Black Creek Basin were minimal, and the values remained within criteria levels established for fish and wildlife by the ADEM (Alabama Department of Environmental Management, 1994). The limited range in pH suggested the stream water was relatively well buffered.

Major Ions

Major ionic constituents in water samples taken at the nine synoptic sites exhibit distinctive variations in both water type and composition. These variations

SITE B-6, BIG BLACK CREEK NEAR LEEDS, ALA., FACING UPSTREAM.

Table 4. Detected water-quality properties and constituents in stream water and bed sediment at nine surface-water sites in the Big Black Creek Basin, August 27, 1997

[mi^2, square mile; ft^3/s, cubic foot per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; —, not applicable; mg/L, milligram per liter; <, less than; µg/L, microgram per liter; µg/g, microgram per gram; mg/kg, milligram per kilogram; NS, not sampled]

Water-quality properties/constituents	Site and USGS downstream order number								
	B-1 02423170	M-1 02423180	B-2 02423183	L-1 02423184	L-2 02423185	B-3 02423187	B-4 02423188	B-5 02423189	B-6 02423190
Field water-quality properties									
Drainage area (mi^2)	10.8	4.84	23.3	5.38	12.2	37.1	37.2	37.9	39.3
Discharge (ft^3/s)	.32	.52	1.8	.096	.98	2.7	2.9	3.3	4.1
Specific conductance (µS/cm)	59	710	367	235	178	271	266	357	332
Water temperature (°C)	24.0	21.5	21.0	24.5	20.5	21.0	21.5	23.0	22.0
Dissolved oxygen (mg/L)	6.5	8.3	5.6	8.6	7.6	6.4	6.7	7.2	7.3
Dissolved oxygen (percent saturation)	—	96	—	—	87	73	77	—	—
pH	7.1	7.6	7.4	8.1	7.2	7.4	7.3	6.8	7.2
Field alkalinity (mg/L as $CaCO_3$)	18	198	133	46	66	103	97	63	66
Color (Platinum/Cobalt units)	15	15	45	21	76	32	30	27	12
Chemical oxygen demand (mg/L)	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Biological oxygen demand, 5-day (mg/L)	0	.9	—	1	.3	.2	—	.4	.5
Hardness (mg/L as $CaCO_3$)	58	80	46	120	21	57	55	100	110
Major ions (mg/L)									
Calcium	11	15	9.2	25	4.3	12	11	20	21
Magnesium	7.5	10	5.6	14	2.5	6.9	6.6	13	13
Sodium	12	121	66	2	2.2	39	34	26	22
Potassium	1.2	2.8	1.8	1.2	.86	1.6	1.6	2	2
Chloride	1.4	1.8	1.6	2	1.5	1.7	1.7	1.7	1.8
Fluoride	< .1	.3	.17	< .1	< .1	.13	.12	.14	.12
Sulfate	22	150	59	3.2	2.5	38	35	99	86
Total dissolved solids	—	585	241	133	—	179	168	232	212
Organic compounds and trace elements (µg/L)									
Carbon disulfide	0.9	0.6	0.3	< 0.2	14.2	< 0.2	4.2	0.8	1.3
Total organic carbon (mg/L)	1.9	4.4	2.5	2.1	1.6	2.3	2.4	2.1	1.5
Total phenols (mg/L)	< 1	< 4	< 4	< 4	< 4	< 4	< 4	< 1	< 4
Oil and grease (mg/L)	< 1	< 1	1	1	< 1	< 1	< 1	< 1	< 1
Aluminum	50	< 10	80	20	50	50	80	300	40

Table 4. Detected water-quality properties and constituents in stream water and bed sediment at nine surface-water sites in the Big Black Creek Basin, August 27, 1997—Continued

[mi^2, square mile; ft^3/s, cubic foot per second; μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; —, not applicable; mg/L, milligram per liter; <, less than; μg/L, microgram per liter; μg/g, microgram per gram; mg/kg, milligram per kilogram; NS, not sampled]

Water-quality properties/constituents	Site and USGS downstream order number								
	B-1 02423170	M-1 02423180	B-2 02423183	L-1 02423184	L-2 02423185	B-3 02423187	B-4 02423188	B-5 02423189	B-6 02423190
Organic compounds and trace elements (μg/L) (Continued)									
Barium	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100
Beryllium	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Cadmium	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Chromium (hexavalent)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Chromium (total)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Copper	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Iron	370	350	910	390	1,700	640	650	3,000	350
Lead	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Manganese	160	110	150	53	190	120	110	750	490
Mercury	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1
Molybdenum	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Nickel	2	2	2	< 1	< 1	1	2	15	8
Zinc	20	20	20	10	20	20	20	30	40
Bed sediment (μg/g)									
Oil and grease (mg/kg)	NS	NS	48.4	< 20	39	24	< 20	24.7	23.9
Arsenic	NS	NS	5	6	7	5	6	26	9
Cadmium	NS	NS	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Chromium	NS	NS	9	25	9	7	11	11	9
Copper	NS	NS	12	7	11	12	14	20	12
Iron	NS	NS	14,000	28,000	13,000	17,000	22,000	25,000	17,000
Lead	NS	NS	10	< 10	< 10	10	< 10	< 10	< 10
Manganese	NS	NS	450	370	300	430	440	310	370
Mercury	NS	NS	.03	.01	.03	.03	.02	.07	.04
Zinc	NS	NS	50	30	40	40	50	40	40

are presented with Stiff and Piper diagrams (figs. 8 and 9, respectively).

Stiff diagrams are used to illustrate variations in water composition by comparing the shape and size of the plots. Sites with similar water compositions exhibit similar shapes, and sites with the greatest ionic concentrations exhibit larger sizes. The diagram plots a polygon, using the percentage composition of the major dissolved ion, in milliequivalents per liter. The percentage composition of major anions (sulfate, chloride + fluoride, carbonate, and bicarbonate) are plotted on the right side of the diagram, and major cations (calcium, magnesium, and sodium + potassium) are plotted on the left side.

Throughout the basin, the dominant anion is bicarbonate, with the exception of sites B-5 and B-6 where sulfate is the dominant anion (fig. 8). The major ionic composition of water in Little Black Creek subbasin (sites L-1 and L-2) is different (more calcium bicarbonate rich) than other basin sites. Water at site L-2 also had the lowest overall content of major ions of sites sampled.

The influence of the sodium-rich water at site M-1 is indicated in the Stiff diagrams of the downstream sites (B-2, B-3, B-4, and B-5) as compared to site B-1, which is upstream from site M-1. A gradual dilution of the sodium-rich water and return to the composition at B-1 is observed at sites B-2, B-3, and B-4. At sites B-5 and B-6, sulfate is the dominant anion, suggesting an additional input or source of sulfate in the ground water at these sites.

A Piper diagram illustrates the composition of water by considering only the major dissolved ions, in milliequivalents per liter. The percentage compositions of major anions and major cations are used as axes in the diagram. For example, a calcium- and bicarbonate-dominant water would plot to the far left-center portion of the diamond area and a sodium- and chloride-dominant water, to the far right-center (fig. 9). The two triangle areas at the base of the Piper diagram provide a further breakdown of the percentage composition of the individual cations (left) and anions (right) in each water sample (fig. 9).

Applications of the Piper diagram include testing groups of water analyses to determine if a water sample is a simple mixture of other samples collected along a flowpath or is affected by dissolution or precipitation. If the water sample is a mixture of two other water samples along a flowpath, it will plot on a straight line formed by the two mixing water samples that are considered endpoints. If the plot is not linear, the water is considered to be affected by other geochemical processes, such as dissolution or precipitation. Inputs into the flowpath that were not accounted for by the available water samples also could cause nonlinearity between samples.

In the stream water of the Big Black Creek Basin, potassium and chloride concentrations were low and relatively constant. Based on that observation, any variations along the sodium + potassium and sulfate + chloride axes were considered to be due to variation in sodium and sulfate, respectively. The relatively low and constant concentration of chloride also was depicted by the triangular anion plot where variation was seen only between bicarbonate and sulfate and where chloride remained less than 10 percent of the anions.

Water composition of samples collected at the nine surface-water sites in the Big Black Creek Basin plotted within three distinct quadrants in the diamond area of the Piper diagram (fig. 9):

(1) Calcium bicarbonate water type included sites L-1, L-2, and B-1, which are all baseline sites in the upper part of the Big Black Creek Basin upstream from Middle Black Creek (site M-1).

(2) Sodium bicarbonate type included site M-1 and three downstream sites on Big Black Creek—sites B-2, B-3, and B-4.

(3) Calcium sulfate type included sites B-5 and B-6, which are downgradient from the landfill on Big Black Creek.

The water at site L-1 on Little Black Creek is almost exclusively a calcium bicarbonate type, and the site represents a baseline site not influenced by coal-mining, landfill, or residential activities. Samples collected at the other baseline sites that are possibly affected by coal-mining activities had a much greater percentage of sulfate. The shift to more sodium- and sulfate-rich water composition was especially evident at site L-2, the baseline site just downstream from site L-1. The water composition at site B-2 on Big Black Creek downstream from the confluence of Middle Black Creek appeared to be influenced by the much higher sodium-sulfate water at site M-1. Assuming simple mixing or dilution of the water composition, site B-2 composition then began to return to baseline site B-1 composition as seen by water compositions at downstream sites B-3 and B-4 that fell along a fairly

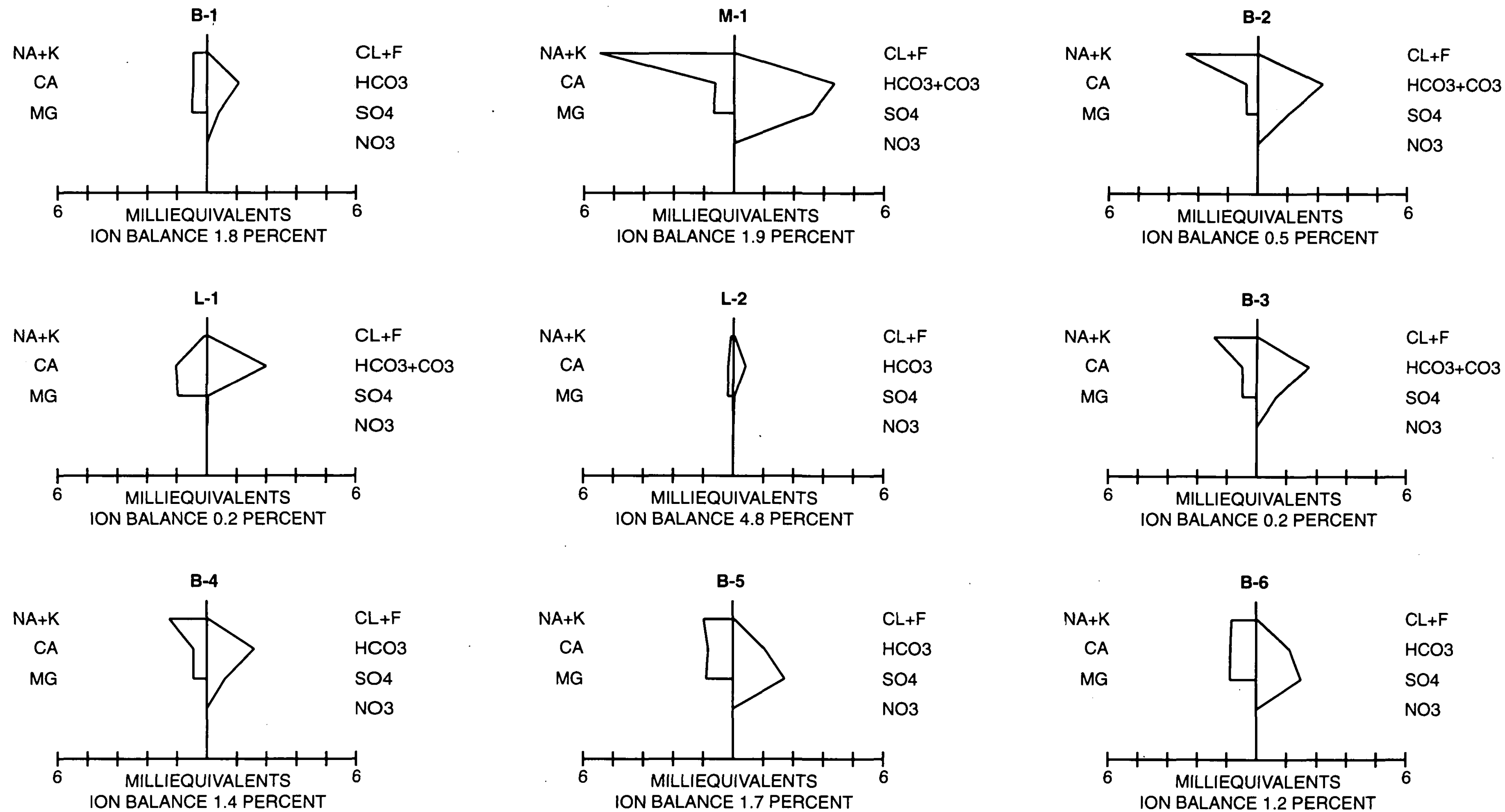

Figure 8. Stiff diagrams of the water chemistry at nine surface-water sites in the Big Black Creek Basin, August 27, 1997.

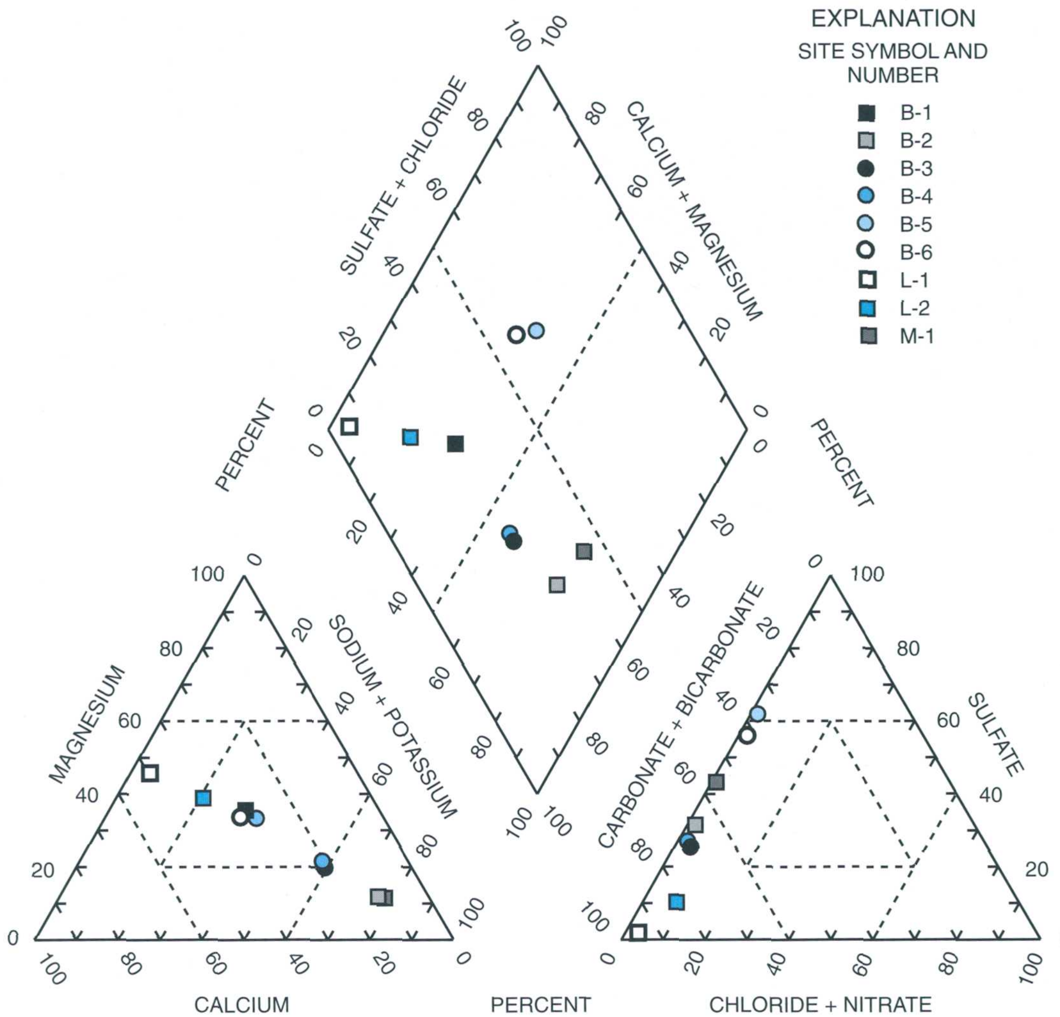

Figure 9. Piper diagrams of the water chemistry at nine surface-water sites in the Big Black Creek Basin, August 27, 1997.

straight line between these two end members. Although cation concentrations at sites B-5 and B-6 can be explained by dilution or mixing of upstream sodium-rich waters with the more calcium-rich water seen at sites B-1and L-1, the elevated sulfate compositions at these sites cannot be explained by simple mixing and suggest a different origin.

A simple dilution model provided further evidence that dilution processes could return the Big Black Creek sites to baseline site B-1 composition, and that additional inputs of sulfate are needed to explain the sulfate concentration at site B-5 (table 5). The simple dilution model was described by Hem (1989) by the equation:

$$C_F = \frac{C_i \cdot Q_i + C_d \cdot Q_d}{Q_i + Q_d}, \qquad (1)$$

where C_i is the initial concentration of solute before dilution,

Q_i is the volume of flow before dilution,

C_d is the concentration of solute in diluting water,

Q_d is the volume of dilution water, and

C_F is the final dilution observed.

The assumption was made that concentrations at site B-1 represented initial or baseline solute concentrations.

Table 5. Difference between estimated and measured sodium concentrations using a simple dilution model
[ft^3/s, cubic foot per second; mg/L, milligram per liter; —, not estimated]

Site number (fig. 2)	Stream discharge (ft^3/s)	Sulfate concentration (mg/L)		Percent difference between measured and estimated	Sodium concentration (mg/L)		Percent difference between measured and estimated
		Measured	Estimated		Measured	Estimated	
B-1	0.32	22	—	—	12	—	—
M-1	.52	150	—	—	121	—	—
B-2	1.8	59	46[a]	22	66	43[a]	53
L-2	.98	2.5	—	—	2.2	—	—
B-3	2.7	38	39[b]	-2.6	39	44[b]	-13
B-4	2.9	35	37[c]	-5.7	34	37[c]	-8.8
B-5	3.3	99	33[d]	67	26	31[d]	-19
B-6	4.1	86	97[e]	-13	22	23[e]	-4.5

[a]Estimated using equation 1, where M-1 is the initial solution, concentration at site B-1 is the diluting concentration, and the discharge at site B-2 minus M-1 is the volume of diluting water.

[b]Estimated using equation 1, where B-2 is the initial solution and L-2 is the diluting solution.

[c]Estimated using equation 1, where B-3 is the initial solution and concentration at site B-1 is the diluting concentration, and the discharge at site B-4 minus B-3 is the volume of diluting water.

[d]Estimated using equation 1, where B-4 is the initial solution and concentration at site B-1 is the diluting concentration, and the discharge at site B-5 minus B-6 is the volume of diluting water.

[e]Estimated using equation 1, where B-5 is the initial solution and concentration at site B-1 is the diluting concentration, and the discharge at site B-6 minus B-5 is the volume of diluting water.

Variations between measured and estimated values for sulfate and sodium concentrations were similar at all sites except B-5 (table 5). The percentage difference between the measured and estimated sodium and sulfate concentrations were relatively low (< 20 percent) at sites B-3, B-4, B-5 (sodium only), and site B-6, suggesting that simple dilution processes could account for their measured concentrations. At these sites, three of the five actual measured concentrations in the stream were overestimated. At site B-2, the estimated values for sodium and sulfate concentrations were significantly lower than the measured values, suggesting that other processes, such as evaporation or additional solute inputs, influenced the solute concentration at that site. The most anomalous result was the comparison of the behavior of sulfate concentrations to sodium concentrations at site B-5. The simple dilution model could explain the sodium concentration but not the measured sulfate concentration at site B-5. This anomaly strongly suggests a second source of sulfate with levels greater than the background water (site B-1).

In addition to high sodium concentrations, the highest alkalinity, total organic carbon, and fluoride concentrations were detected at site M-1. Sulfate concentration at this site was the highest in the upper basin, although sites B-5 and B-6 had the highest overall sulfate concentrations. Chloride levels in the ground-water monitoring well at the landfill ranged from 4.8 to 59.5 milligrams per liter (mg/L) from 1992 to 1996 (Guardian Systems, 1992, 1994, 1995, 1996), but no increases in chloride concentrations were identified at sites B-4, B-5, and B-6 downgradient from the landfill.

Organic Compounds

The presence of certain manmade VOCs in the stream water and in the ground water discharging to the stream could indicate landfill-derived contamination rather than surface and subsurface coal-mine drainage. Ground-water monitoring reports to the ADEM (Guardian Systems, 1992, 1994, 1995, 1996) from the Acmar Regional Landfill indicated that ethane-based solvents (specifically 1,1-dichloroethane, 1,1,1-trichloroethane, and chloroethane) were detected periodically in the ground-water system downgradient from the active cells. The solvents were detected at levels of 2 to 70 micrograms per liter (μg/L). These solvents were not detected in samples taken from ground-water monitoring wells sampled in 1996.

The drive-point wells B-4-WL, B-5-WL, and B-5-WR sampled the zone in the streambank that contains water of both subsurface and stream channel origin at sites B-4 and B-5 (fig. 2). At site B-5, chloromethane (methyl chloride) was detected at a concentration of 0.34 μg/L in the drive-point well B-5-WL downgradient from the landfill and iodomethane, at a concentration of 0.21 μg/L in the drive-point well B-5-WR upgradient from the landfill (table 6). The minimum reporting level (MRL) for the overall VOC analysis was 0.2 μg/L; however, the instrument calibration for 1,1-dichloroethane was conducted at 0.1 μg/L making detections above this calibration level valid (D. Rose, U.S. Geological Survey National Water Quality Laboratory, written commun., October 1997). The solvent 1,1-dichloroethane was detected only in the drive-point well B-4-WL at a concentration of 0.11 μg/L (table 6). This drive-point well was located immediately downgradient from the active cells of the landfill.

Table 6. Volatile organic compounds detected in water sampled from drive-point wells at selected sites in the Big Black Creek Basin, August 27, 1997

Volatile organic compound	Concentration (micrograms per liter)		
	Well B-4-WL	Well B-5-WR	Well B-5-WL
Carbon disulfide	3.71	0.34	0.19
Iodomethane	< .20	.21	< .40
Chloromethane (Methyl chloride)	< .20	< .20	.34
1,1-Dichloroethane	.11[a]	< .20	< .40

[a]Concentration was below the minimum reporting level of 0.2 microgram per liter, but instrument calibration for 1,1-dichloroethane was set at 0.1 microgram per liter making the value valid (D. Rose, U.S. Geological Survey National Water Quality Laboratory, written commun., October 1997).

During this investigation, ethane-based VOCs were not detected in the field blank or stream-water synoptic samples at any of the nine sites (app. 2). The only VOC frequently detected in stream-water samples was carbon disulfide (table 4), which can be naturally derived from the reaction of organic constituents of coal and sulfur and the biodegradation of organic material. The range in concentrations of carbon disulfide was from less than 0.2 μg/L (sites L-1 and B-3) to 14.2 μg/L (site L-2) (table 4). Bioaccumulation of carbon disulfide by biota is predicted to be low (U.S. Environmental Protection Agency, 1986). Carbon disulfide has a moderate acute aquatic toxicity ranging from 1 to 100 mg/L. All reported human exposure (chronic and acute) levels are in the parts per million range, well above the levels detected in the stream.

Oil and grease concentrations in the stream water were at or below the detection limit of 1 mg/L at all sites in the basin. Two sites (sites B-2 and L-1), both of which were baseline sites, had detectable levels of oil and grease. Oil and grease was detected in the bed sediment of the stream at baseline sites B-2, L-2, and B-3 and at sites B-5 and B-6, downgradient from the landfill. The detected levels ranged from 23.9 milligram per kilogram (mg/kg) at site B-6 to 48.4 mg/kg at site B-2, with the higher concentrations occurring in the baseline sites. All detected levels of oil and grease were below the ADEM's corrective action level of 100 mg/kg. Phenols were not detected in the stream water at any of the nine sites. Semivolatile organic compound scans of the bed sediment identified the greatest presence (number of peaks and peak area) of these compounds at sites with the greatest coal particles in the bed sediment. These sites, in ascending order, are L-2, B-1, B-4, B-6, and B-5. These results suggest a dominant coal, rather than landfill, source of the semivolatile compounds.

Trace Elements

Water draining the Pottsville Formation in the Big Black Creek Basin is generally low in dissolved solids because the sandstone is resistant to weathering and contains few readily soluble minerals. However, where coal beds are present and mined, water draining from coal mines or tailings piles can be strongly acidic and highly mineralized as a consequence of oxidation of metal sulfides and the subsequent mobilization of associated trace elements that are present in the coal. These conditions can cause environmental problems because most organisms cannot tolerate strong acidic conditions or elevated levels of certain trace elements. Trace elements in coal, which are of moderate to high concern because of their potential toxicity and relatively high mobility, include arsenic, barium, cadmium, chromium, copper, fluorine, mercury, molybdenum, nickel, lead, and zinc. Beryllium and thallium are considered to remain relatively inert in the coal residue and are of low concern (Wilson and others, 1980).

Ground-water samples were analyzed for antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc as part of the ground-water monitoring at Acmar Regional Landfill (Guardian Systems, 1992, 1994, 1995, 1996). In general, the reported levels of arsenic, barium, nickel, and zinc were well above the analytical detection limits (5, 50, 10, and 30 µg/L, respectively) for ground water in most monitoring wells from 1992 to 1996. During base-flow periods (September), arsenic concentrations ranged from < 5 to 120 µg/L; barium concentrations ranged from < 50 to 3,170 µg/L; nickel concentrations ranged from < 10 to 94 µg/L; and zinc concentrations ranged from < 30 to 100 µg/L. Cadmium, chromium, and lead concentrations were rarely above their detection limits (1, 20, and 3 µg/L, respectively). Antimony, beryllium, cobalt, copper, selenium, silver, and thallium concentrations were less than detection limits in all wells (5, 1, 500, 20, 5, 20, and 5 µg/L, respectively).

The synoptic sampling of the stream water in Big Black Creek during this investigation determined that barium, beryllium, cadmium, chromium (hexavalent and total), copper, lead, mercury, and molybdenum concentrations were below detection limits (100, 10, 1, 1, 1, 10, 1, 0.1, and 1 µg/L, respectively) at all nine sites, including sites B-4, B-5, and B-6 downgradient from the landfill (table 4). These findings are somewhat contradictory to what would be expected if large quantities of trace-element enriched leachate were entering the stream downgradient from the landfill. A rise in concentrations above detection limits could be expected in the stream downgradient of the landfill, but no apparent enrichment in these trace elements was observed.

Detectable levels of the trace elements aluminum, iron, manganese, nickel, and zinc were present in the stream water of Big Black Creek and its tributaries during the synoptic sampling event (table 4). Total recoverable aluminum concentrations in stream water in the Big Black Creek Basin ranged from < 10 µg/L at site M-1 to 300 µg/L at site B-5; iron concentration ranged from 350 µg/L at sites M-1 and B-6 to 3,000 µg/L at site B-5; manganese concentrations ranged from 53 µg/L at site L-1 to 750 µg/L at site B-5; nickel concentrations ranged from < 1 µg/L at sites L-1 and L-2 to 15 µg/L at site B-5; and zinc concentrations ranged from 10 µg/L at site L-1 to 40 µg/L at site B-6 (table 4).

In general, the maximum concentrations of the detected trace elements were observed at sites B-5 and B-6 downgradient from the coal wash and landfill. No significant increase was noted in iron, manganese, nickel, and zinc between site B-4 (downgradient from the landfill but not the coal wash) and the upstream sites. This lack of enrichment at site B-4 suggests that the elevated trace-element levels could have been from the coal wash, not the landfill, during this synoptic sampling event.

Bed sediment at sites B-2, L-1, L-2, B-3, B-4, B-5, and B-6 was also sampled and analyzed for trace-element concentrations during the synoptic water-quality investigation (table 4). Overall, the greatest trace-element concentrations in the bed sediment was at site B-5, downstream from the coal wash. Cadmium was not detected in the bed-sediment at any of the sites. Lead was detected at sites B-2 and B-3 at a concentration of 10 micrograms per kilogram (µg/kg) (fig. 10; table 4). Mercury was detected at all sites at concentrations that ranged from 0.01 µg/kg at site L-1 to 0.07 µg/kg at site B-5 (fig. 10; table 4). Arsenic, chromium, and copper were detected in the bed sediment at all sites at about the same concentrations, which ranged from 5 to 26 µg/kg, 7 to 25 µg/kg, and 7 to 20 µg/kg, respectively. Site B-5 had the greatest concentrations of arsenic and copper; site L-1 had the greatest chromium concentration (fig. 10; table 4). Manganese and iron concentrations at all sites were one to four times higher, respectively, than the other trace elements (fig. 10).

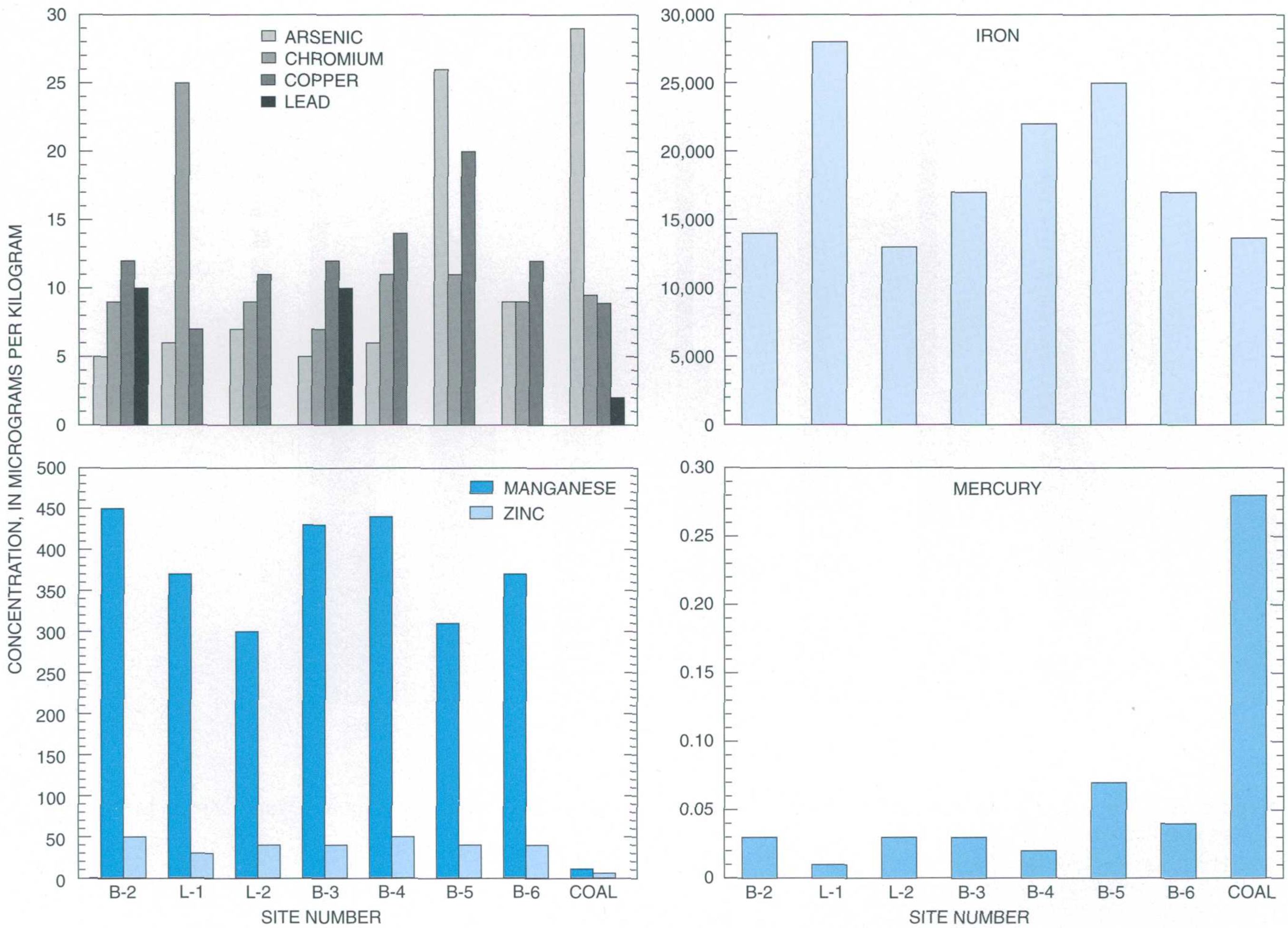

Figure 10. Trace-element concentrations in bed sediment at selected surface-water sites in the Big Black Creek Basin and median trace-element concentrations in coal from the Cahaba Coal Field, Alabama, August 27, 1997.

Concentrations of selected trace elements detected in the water column were compared graphically with those detected in the bed sediment (fig. 11). This graphic comparison identified a change in the ratio of water-column to bed-sediment concentrations for manganese and zinc at sites B-5 and B-6, as compared to upstream sites B-2, B-3, and B-4; and for iron at sites L-2 and B-5, as compared to upstream sites. These changes suggest different geochemical equilibrium conditions at these sites.

Instantaneous loads and yields of constituents in the stream water at the nine water-quality sites were computed to normalize the concentrations to stream discharge (loads) and drainage areas (yields) which provided greater comparability between sites (table 7). Yields are loads divided by the drainage area and allow a more direct comparison between subbasins of different size. Elevated instantaneous loads and yields for iron, manganese, aluminum, and nickel were observed at site B-5, located downgradient from the landfill and immediately downstream from the abandoned coal wash. The yields at site B-5 were greater than those at site B-4, located downgradient from the landfill, upstream from the coal wash, and within the same channel reach of relatively high ground-water discharge, as indicated in the streamflow investigation (fig. 7; table 3).

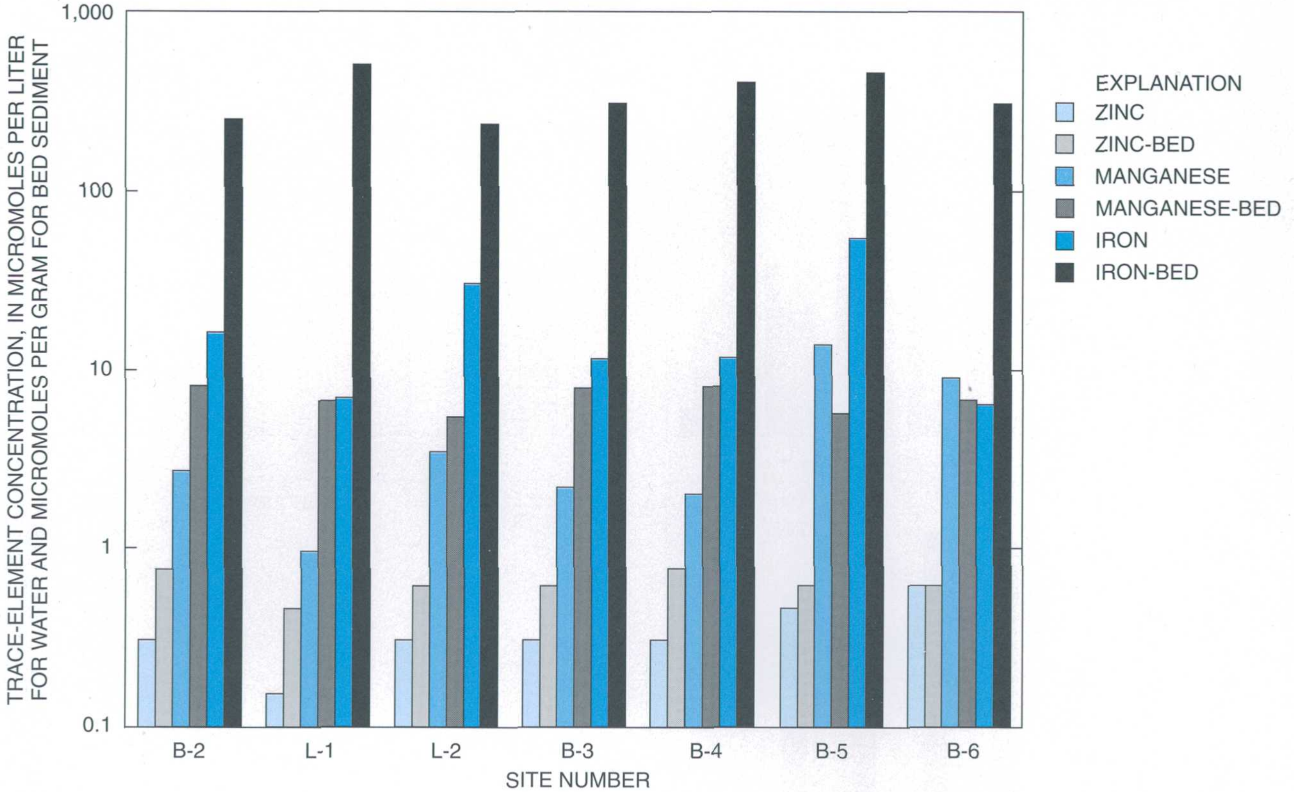

Figure 11. Trace-element concentrations in water and bed sediment (BED) at selected surface-water sites in the Big Black Creek Basin, August 27, 1997.

Table 7. Instantaneous load and yield of selected constituents at surface-water sites in the Big Black Creek Basin, August 27, 1997

Site no. (fig. 2)	Nickel	Zinc	Sulfate	Aluminum	Manganese	Iron
Constituent load (ton per day)						
B-1	1.73	17.3	19.0	43.2	138	319
M-1	2.80	28.0	210	0	154	491
B-2	9.71	97.1	286	388	728	4,420
L-1	0	2.59	.827	5.18	13.7	101
L-2	0	52.9	6.61	132	502	4,490
B-3	7.28	146	277	364	874	4,660
B-4	15.6	156	274	626	860	5,080
B-5	134	267	881	2,670	6,680	26,700
B-6	88.5	442	951	442	5,420	3,870
Constituent yield (ton per day per square mile)						
B-1	0.160	1.60	1.76	4.00	12.8	29.6
M-1	.580	5.80	43.5	0	31.9	101
B-2	.417	4.17	12.3	16.7	31.3	190
L-1	0	.481	.154	.962	2.55	18.8
L-2	0	4.33	.542	10.8	41.2	368
B-3	.196	3.93	7.46	9.81	23.6	126
B-4	.421	4.21	7.36	16.8	23.1	137
B-5	3.52	7.04	23.3	70.4	176	704
B-6	2.25	11.3	24.2	11.3	138	98.5

A schematic representation of the basin was used to display the computed yields of iron, sulfate, manganese, zinc, nickel, and aluminum (fig. 12). A significant increase in yields occurred at site B-5 (iron, nickel, and manganese) and site B-6 (sulfate and zinc). Sulfate yield was greatest at site M-1 on Middle Black Creek, and a relatively high iron yield was present at site L-2 on Little Black Creek. The baseline site L-1, located upstream from coal-mining and landfill activities, consistently had the lowest yield of these constituents in the basin. Site B-6, located downstream from site B-5, generally had lower yields than site B-5, suggesting dilution by ground-water discharge to streams within the region (table 7).

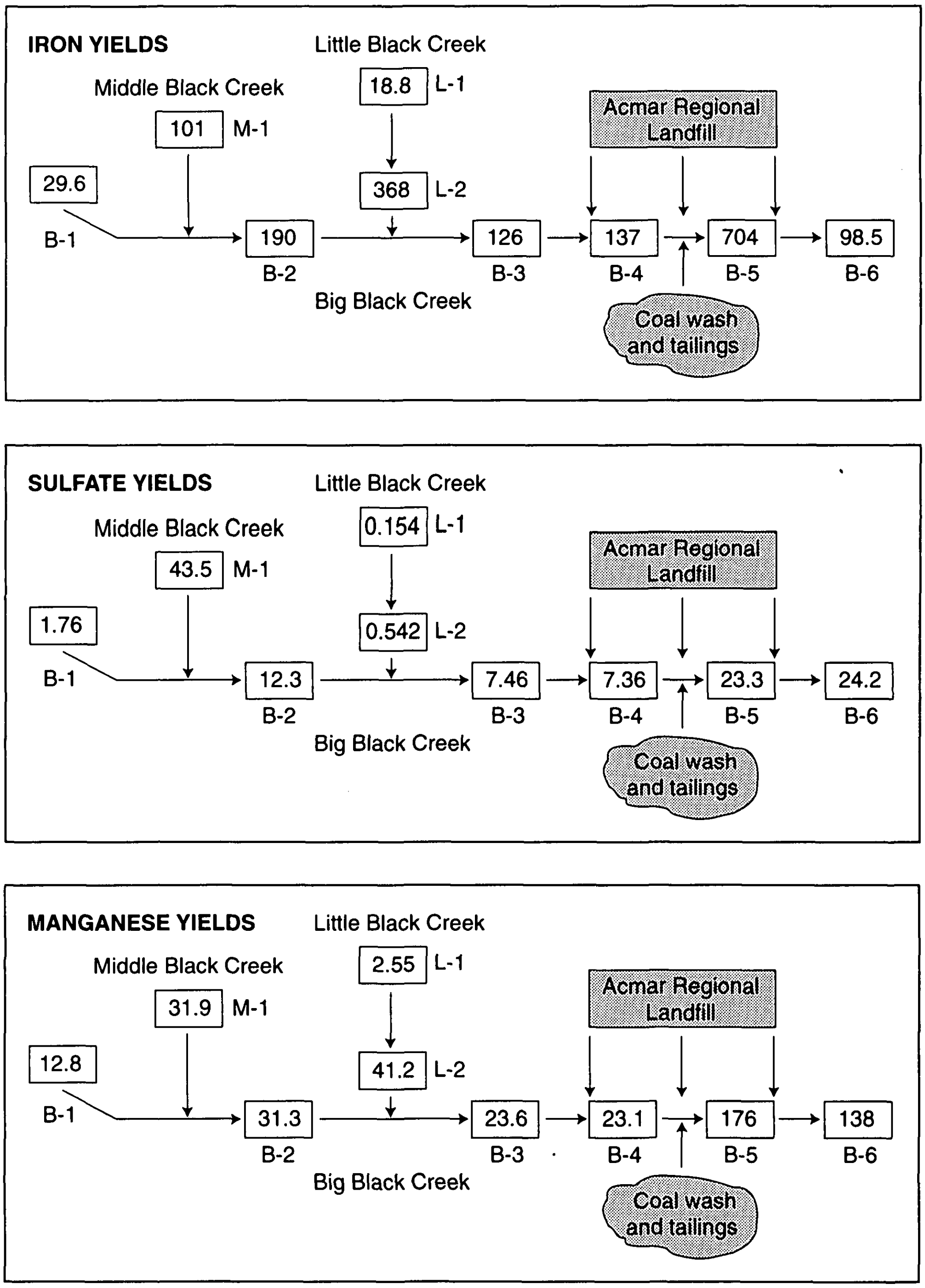

Figure 12. Instantaneous yields of selected constituents, in tons per day per square mile, at surface-water sites in the Big Black Creek Basin, August 27, 1997.

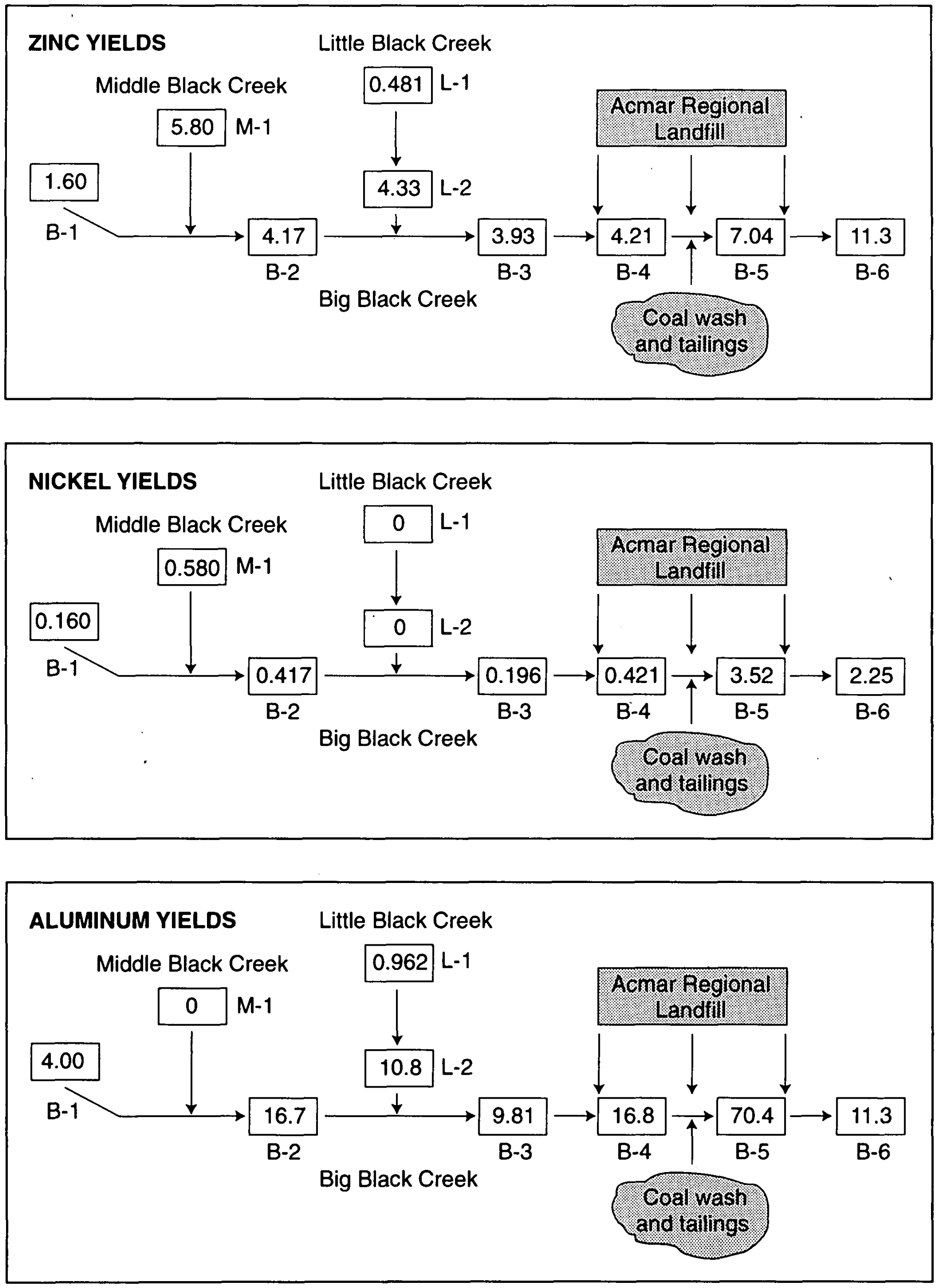

Figure 12—Continued. Instantaneous yields of selected constituents, in tons per day per square mile, at surface-water sites in the Big Black Creek Basin, August 27, 1997.

Geochemical Analysis

Geochemical analysis of the water-quality data can determine if the losses and gains seen in the analysis can be explained by geochemical processes of precipitation and dissolution or by instream dilution and evaporation processes. The net gain/loss analysis assumes that certain dissolved constituents in stream water behave conservatively; however, geochemical reactions (such as, oxidation, precipitation, or dissolution) that can occur along the hydrologic flow path can remove or add trace elements to the stream water.

The WATEQ4F computer program (Ball and others, 1987) computes major-ion and trace-element speciation and mineral saturation for natural waters. This program requires the input of the field measurements of temperature, pH, dissolved oxygen, and alkalinity and the chemical analysis of a water sample. The program calculates the distribution of aqueous species, ion activities, and mineral saturation indices and indicates the tendency of the water to dissolve or precipitate a set of minerals. A positive saturation index indicates that the water is oversaturated with respect to the mineral and would tend to precipitate that mineral by removing associated ions from solution (loss). A negative saturation index indicates that the water is undersaturated with respect to the mineral and would tend to dissolve that mineral by adding associated ions to solution (gain).

Saturation indices for selected mineral species were computed by the WATEQ4F program (table 8). The indices for the aluminum hydroxide mineral species (boehmite and gibbsite) and iron oxy-hydroxide mineral species ($Fe_3(OH)_8$, ferrihydrite, and goethite) indicate that the stream water at all sites was (1) oversaturated with respect to all iron oxy-hydroxide species and gibbsite and (2) saturated to oversaturated with respect to boehmite. These conditions suggest that the stream water loses aluminum and iron from solution downstream as a result of precipitation of these species. The presence of red-orange, amorphous, iron oxy-hydroxide precipitate in pooled or slower velocity areas of the Big Creek and its tributaries agrees well with the geochemical speciation model. Continual sources of iron to solution would be from the dissolution of pyrite and siderite present in the bedrock, and of aluminum and silicate minerals (feldspars and micas).

Of the carbonate mineral species, calcite and dolomite saturation indices indicated undersaturated conditions at most sites. The exception was site M-1, which was near saturated conditions (table 8). Undersaturated conditions of the stream water, with respect to calcite and dolomite, suggest that bicarbonate, calcium, and magnesium ions are added to solution by dissolution of these carbonate minerals in the bedrock and coal deposits.

Rhodochrosite, the manganese carbonate species, had indices that were near saturation at most sites; however, the indices for manganese hydroxide species (manganite) represented undersaturated conditions at all sites. This difference in saturation indices between the two species groups suggests that the removal of manganese from the stream would be by precipitation of its carbonate species. These results indicate manganese could be added to the stream water by dissolution of its hydroxyl species but would not be removed by precipitation. The absence of the black manganese oxy-hydroxide precipitate in Big Black Creek and its tributaries agrees well with the geochemical speciation model.

Water-Quality Assessment

Trace-element and organic compound concentrations that were detected during the synoptic water-quality sampling were below established water-quality standards and criteria for the State of Alabama (Alabama Department of Environmental Management,

SITE B-4, BIG BLACK CREEK ABOVE WHITES CHAPEL, ALA., WITH ACMAR REGIONAL LANDFILL IN BACKGROUND.

Table 8. Saturation indices for selected mineral species computed by the WATEQ4F computer program for synoptic water samples collected at selected surface-water sites in the Big Black Creek Basin, August 27, 1997

[Negative values represent undersaturated conditions; positive values represent oversaturated conditions; values between 0.5 and -0.5 represent saturated conditions]

Site no. (fig. 2)	Aluminum hydroxide species		Iron oxy-hydroxide species			Carbonate species				Manganese hydroxide species	Zinc species
	Boehmite $AlO(OH)$	Gibbsite $Al(OH)_3$	$Fe_3(OH)_8$	Ferrihydrite $FeO(OH)$	Goethite $Fe(OH)$	Siderite $FeCO_3$	Calcite $CaCO_3$	Dolomite $CaMg(CO_3)_2$	Rhodochrosite $MnCO_3$	Manganite $MnO(OH)$	$Zn(CO_3)H_2O$
B-1	1.19	1.68	1.06	1.34	7.23	-0.861	-1.36	-2.55	-0.722	-6.37	-2.72
M-1	-.177	.343	3.11	2.02	7.91	-.014	-.390	-.181	-.014	-5.75	-2.01
B-2	1.27	1.80	3.55	2.14	8.03	.180	-.931	-1.78	-.303	-5.93	-2.71
L-1	-.202	.279	4.27	2.43	8.32	-.457	.335	-.769	-.131	-4.91	-2.03
L-2	1.25	1.79	3.70	2.19	8.08	-.286	-2.09	-4.12	-.936	-6.04	-2.87
B-3	1.08	1.61	3.18	2.03	7.92	-.045	-.903	-1.74	-.460	-5.98	-2.38
B-4	1.35	1.87	2.73	1.88	7.78	-.135	-1.05	-2.01	-.597	-6.18	-2.33
B-5	2.29	2.79	1.92	1.62	7.52	-.105	-1.50	-2.86	-.441	-6.34	-2.76
B-6	1.14	1.63	1.39	1.44	7.33	-.645	-1.04	-2.00	-.212	-5.73	-2.34

1994), with the exception of secondary (aesthetic) drinking-water levels for iron and manganese (table 9). Oil and grease detected in the bed sediments was below the corrective action limit of 100 mg/kg (table 4).

The synoptic water-quality investigation results identified no distinguishing features or spatial pattern of contamination that could be attributed solely to landfill activities. No significant increases in chloride levels, specific conductance, total dissolved solids, color, or biochemical oxygen demand were observed at sites downgradient from the landfill (table 4).

Elevated sulfate and trace-element concentrations were identified at site B-5, which is downstream from the abandoned coal wash and downgradient from the landfill. The ground-water discharge for the immediate upstream reach between sites B-3 and B-4 (also downgradient from the landfill but upstream from the coal wash) was 1.3 $(ft^3/s)/mi^2$, less than between sites B-4 and B-5 (0.57 $(ft^3/s)/mi^2$). But no significant enrichment of sulfate or trace elements was observed at site B-4. Therefore, the coal wash could be presumed to exert a greater influence than the landfill on the water-quality at site B-5 at the time of sampling.

Either landfill activities contributed no significant contamination to Big Black Creek during the synoptic sampling at base-flow conditions, or the presence of coal-mining and residential activities in the

Table 9. Criteria and standards for selected constituents and compounds detected during synoptic water-quality sampling in the Big Black Creek Basin, August 27, 1997

[µg/L, microgram per liter; —, no established criteria or standard]

Contaminant	Alabama Water Quality Standards [Federal Water Quality Criteria]			Alabama Drinking Water Standards	
	Human health	Aquatic organisms[a]			
	Fish consumption (µg/L)	Freshwater, acute (µg/L)	Freshwater, chronic (µg/L)	Primary[b] (µg/L)	Secondary[c] (µg/L)
Trace elements					
Aluminum	—	750	87	—	—
Arsenic	0.14	360	190	50	—
Barium	.078	—	—	2,000	—
Beryllium	—	—	—	4	—
Cadmium	—	—	—	5	—
Chromium (total)	—	1,300[d]	160[b]	100	—
Chromium (hexavalent)	—	16	11	—	—
Copper	—	13[b]	9[b]	—	1,000
Iron	—	—	—	—	500
Lead	—	52[b]	2[b]	15[e]	—
Manganese	—	—	—	—	50
Mercury	.15	2.4	.012	2	—
Molybdenum	—	—	—	—	—
Nickel	4,600	1,300[b]	1,300[b]	100	—
Zinc	—	87[b]	78[b]	—	—
Organic compounds					
Chloromethane	—	—	—	—	—
Iodomethane	—	—	—	—	—
1,1-Dichloroethane	—	—	—	—	—
Oil and grease	—	—	—	—	—

[a]Aquatic life criteria from Alabama Department of Environmental Management (ADEM) Administrative Code 335-6-11.02.

[b]Alabama Drinking Water Standards, Primary Drinking Water Standards, maximum contamination levels, ADEM Administrative Code 335-7-2.03, January 1996.

[c]Alabama Secondary Drinking Water Standards, ADEM Administrative Code 335-7-3.02, January 1996.

[d]Computed based on an average hardness of 70 mg/L and a pH of 7.

[e]Action level at tap.

basin served to mask any contributions made by the landfill. Landfill-derived trace elements, total dissolved solids, acidity, and biochemical oxygen demand supplied to the stream by ground-water discharge was not definitively identified as such.

VOCs were not detected in the stream system, but the detection of 1,1-dichloroethane (the same solvent detected in the ground-water monitoring system at the landfill) in the water sample from the drive-point well B-4-WL downgradient from the landfill at site B-4 could indicate that the landfill-derived leachate has migrated off site to the stream at below detectable levels. The potential exists for water-quality degradation of the stream by landfill leachate if the level of contamination increases.

In addition to dilution by streamflow, geochemical processes, including precipitation of iron and aluminum hydroxides and dissolution of calcite and pyrite, control the levels of dissolved constituents in the stream water and in the bed sediment. Computed yields of trace elements reflect the combined effects of all these processes. In general, the greatest yields of trace elements were observed at sites B-5 and B-6, downstream from the abandoned coal wash.

Benthic Invertebrate Communities

The benthic invertebrate communities are affected by changes in water quality. Therefore, measures of community balance and diversity of benthic invertebrates at selected sites in the Big Black Creek Basin offer a useful starting point for discerning possible water-quality differences between these sites. The data collected during the benthic invertebrate community sampling are shown in appendix 1. Because only one sampling run was made for this project, long-term data are not available; therefore, assessments of the benthic invertebrate communities are only for the time of sampling.

Healthy benthic invertebrate communities support diverse groups of taxa. A community in which one taxon is overwhelmingly more common than the others is probably stressed. Community balance can be quickly assessed by calculating the percent contribution of the dominant taxon. At site B-2, for example, more than a quarter of the total organisms collected were from a genus of mayfly, *Stenonema*. According to Harris (1987), "Mayfly nymphs, in general, tend to be intolerant of habitat degradation, and are widely used as pollution indicators." However, the fact that this one taxon composed a large proportion of the community may have indicated that other taxa were being restricted by some aspect of water quality or habitat. The most common group at site B-6 was a chironomid, or midge genus, *Rheotanytarsus sp.*, accounting for 16.6 percent of the total number of individuals. The family of baetid mayflies were also common at site B-6, contributing 20.8 percent of the total number of individuals to the sample. Baetid mayflies are considered intolerant of acidification (Johnson and others, 1993), and their presence in such abundance at site B-6 suggested that acidification may not be a problem at that site. At sites B-5 and L-1, the dominant taxa contributed less than 10 percent of the total individuals, indicating more balanced communities than found at B-2 and B-6.

Taxonomic data were used to compute total taxa richness, EPT index, chironomid taxa richness, and BI values and were compared with ranges of metric values from the ADEM reference site TCT-5 on Talladega Creek (Diggs and Hulcher, Alabama Department of Environmental Management, written commun., April 1998) (table 10). The ranges of metric values for site TCT-5 shown in table 10 are only for the three instream habitat types (root/bank, log/rock, and riffle) that were also sampled in the Big Black Creek Basin. In figures 13 and 14, the metric values from site TCT-5 that were most indicative of a healthy benthic invertebrate community are grouped as TCT-5B, and the metric values from site TCT-5 that were least indicative of benthic invertebrate community health are grouped as TCT-5W.

Table 10. Calculated metrics for selected sites in the Big Black Creek Basin, July 16–17, 1997, and ranges of metric values for ADEM reference site TCT-5 at Talladega Creek

Metric	Site no. (fig. 2)				TCT-5
	B-6	B-5	B-2	L-1	
Total taxa richness	66	61	52	72	45–67
EPT index	14	14	11	16	19–25
Chironomid taxa richness	26	14	16	20	12–13
Biotic index	5.59	5.17	4.69	4.77	3.4–4.1

The reference site on Little Black Creek (L-1) had the greatest total taxa richness, or number of distinct taxa, even exceeding the maximum number of taxa found at the ADEM reference site. In the Big Black Creek Basin, lowest taxonomic diversity occurred above the landfill at site B-2, with richness then increasing at the downstream sites, B-5 and B-6. Taxa richness at sites B-2, B-5, and B-6 were in the same range as taxa richness values at site TCT-5 (table 10).

The EPT index value for the L-1 sample was 16. Despite having the highest proportion of individuals of Ephemeroptera (53.8 percent) of any of the sites in the Big Black Creek Basin, site B-2 had only 11 EPT taxa. Samples from sites B-5 and B-6 each had 14 EPT taxa. All EPT index values in the Big Black Creek Basin were less than those at site TCT-5.

Chironomid taxa richness was highest at site B-6, downstream of the landfill. The lowest number of chironomid taxa in the Big Black Creek Basin was 14 at site B-5, adjacent to the landfill. All of the sites in the Big Black Creek Basin had more chironomid taxa than did site TCT-5.

As shown in figure 13, chironomid taxa equalled or exceeded EPT taxa in all of the Big Black Creek Basin sites. However, at site TCT-5, intolerant EPT taxa were more common than tolerant chironomids. This seems to indicate that the water quality was worse at the Big Black Creek Basin sites at the time of sampling than at reference site TCT-5. However, seasonal differences between the times of sampling in the Big Black Creek Basin and at site TCT-5 may account for the lower EPT index values at the Big Black Creek Basin sites. The Plecoptera were nearly absent at the Big Black Creek Basin sites during July, probably due to adults of that order emerging from the streams before the time of sampling (C. Couch, U.S. Geological Survey, oral commun., October, 1997; Brigham and others, 1982).

BI values indicate that the selected sites in the Big Black Creek Basin are similar in terms of pollution. Values ranged from 4.69 at site B-2 to 5.59 at site B-6 (fig. 14; table 10). The range of BI values at site TCT-5 was lower, indicating better water quality, than any of the values found in the Big Black Creek Basin. Again, the absence of intolerant Plecoptera may have caused the BI values in the Big Black Creek Basin to be greater than those at site TCT-5.

BI values are the average tolerance values for the benthic invertebrate communities. To look for changes in the communities of intolerant organisms, a break point tolerance value was chosen. The number of taxa and number of individuals that had tolerance values equal or less than 3.0 were counted for each site and considered intolerant. The sample from site L-1 had 17 intolerant genera, contributing 168 individuals. Site B-2 only had one intolerant genus present, contributing one individual. Sites B-5 and B-6 had three intolerant genera, contributing 7 and 6 individuals, respectively. The downstream sites have experienced a loss of intolerant organisms in their benthic invertebrate

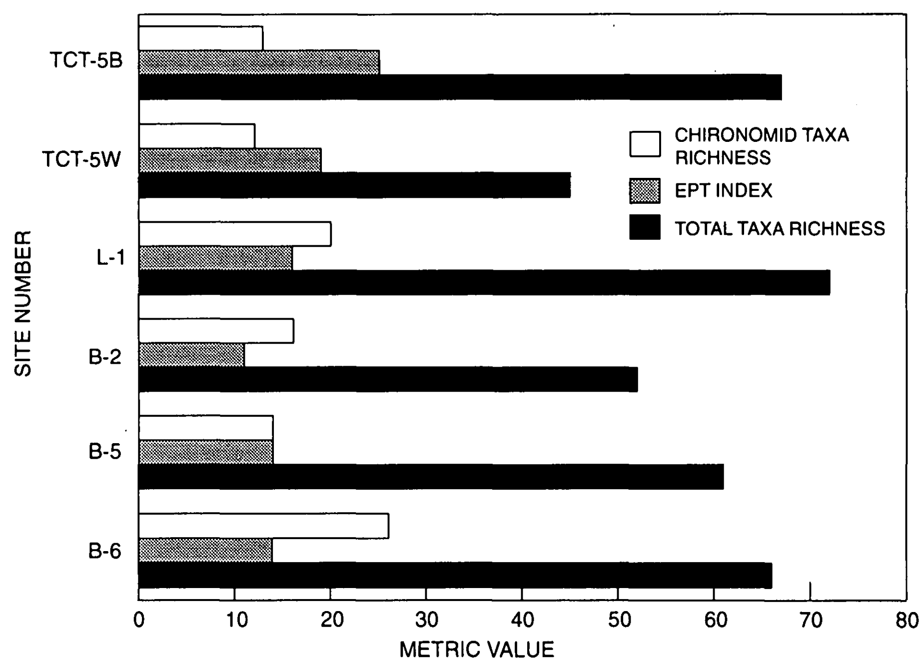

Figure 13. Metric values based on benthic invertebrate communities in the Big Black Creek Basin, July 16–17, 1997.

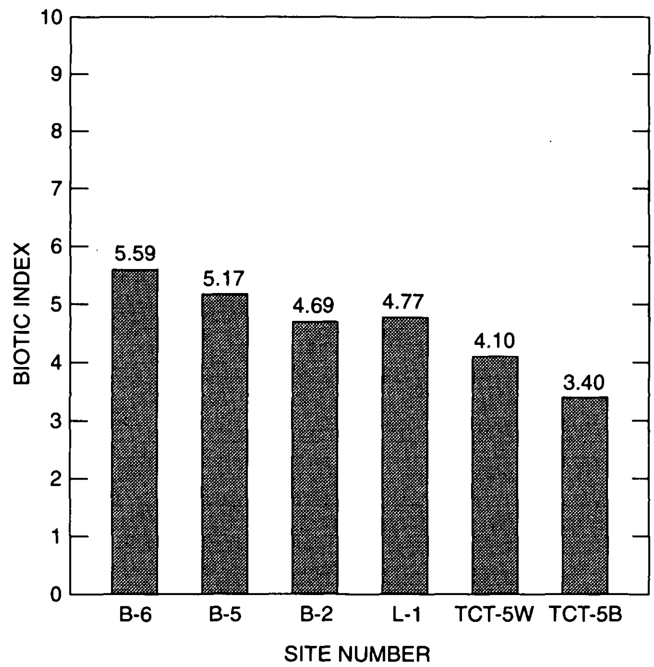

Figure 14. Biotic index values based on the results of the benthic invertebrate community survey in the Big Black Creek Basin, July 16–17, 1997.

communities, but the loss is greatest at site B-2, the site above the landfill. The seemingly contradictory BI value at site B-2 is probably because individuals of the relatively intolerant (tolerance value=3.5) genus *Stenonema* account for approximately 28 percent of the entire sample.

The ADEM has developed criteria for the benthic invertebrate communities of Appalachian streams of North Alabama. The ADEM criteria and corresponding reference data from Talladega Creek are summarized in table 11. These criteria and data are from all six instream habitats described in the ADEM's Standard Operating Procedures (Alabama Department of Environmental Management, 1996). Metric values calculated from only the riffle, root/bank, and log/rock

Table 11. ADEM benthic criteria and data for reference site TCT-5 at Talladega Creek

[>, greater than; <, less than]

Metric	Benthic criteria			Talladega Creek
	Unimpaired	Slightly Impaired	Impaired	
Total taxa richness	> 55	36–55	< 36	73–85
EPT taxa	> 15	10–15	< 10	29–30
Chironomid taxa	> 16	11–16	< 11	16–21
Biotic index	< 4.7	4.7–6.0	> 6.0	4.2–4.5

instream habitats at site TCT-5 are in the unimpaired category of the criteria for all except Chironomid taxa and the low end of total taxa richness. Composite data from these three instream habitats at other unimpaired sites should relate similarly to the criteria. Therefore, comparison of the metrics from the Big Black Creek Basin with these criteria is meaningful.

Total taxa richness ranged from 72 at site L-1 to 52 at site B-2 in the Big Black Creek Basin during the July 1997 synoptic survey and, under the ADEM's criteria for similar streams, only site B-2 would be considered slightly impaired. The number of EPT genera ranged from 11 at site B-2 to 16 at site L-1. Sites B-2, B-5, and B-6 are in the slightly impaired group according to the ADEM's EPT criteria, and site L-1 is considered unimpaired. Twenty-six chironomid genera were collected at site B-6, which was more than were collected at the ADEM's reference site. Site L-1 also had chironomid taxa counts in the unimpaired range. Sites B-5 and B-2 are in the slightly impaired category. All of the synoptic sampling sites had higher BI values than the six habitat samples collected at Talladega Creek. Only site B-2 is in the unimpaired category.

Water-quality data presented earlier indicated that trace element and sulfate concentrations increased at sites B-5 and B-6. Also there is a high concentration of sodium at site B-2. These water-quality differences may account for some of the differences between the communities at site B-2 and sites B-5 and B-6. For instance, the greater number of chironomid taxa at site B-6 are typical of water with greater trace-element concentrations. A similar increase in chironomid taxa is not seen at site B-5. This is probably due to habitat differences between the sites. Although an extensive habitat survey was not conducted, it was noted that site B-5 had a much larger riffle area with higher velocities than the other two sites on Big Black Creek. At the time of the August synoptic water-quality investigation, dissolved oxygen levels at site B-2 were lower than at the other sites included in the July synoptic benthic invertebrate investigation.

The results of the synoptic benthic invertebrate community investigation indicated that the benthic invertebrate communities at sites B-2, B-5, and B-6 differed from the community at the reference site L-1. In particular, fewer intolerant genera of benthic invertebrates were present in the communities of sites B-2, B-5, and B-6 than were at site L-1. Site B-2, upgradient from the landfill, also seemed to support a different benthic invertebrate community from sites B-5 and B-6. Low total taxa richness and EPT index values for site B-2 suggest the benthic invertebrate community was stressed. The BI value at site B-2 seems to conflict with this assessment but is probably skewed due to a disproportionate number of the individuals being from a single genus. Sites B-5 and B-6, downgradient from the landfill, seem to support more diverse benthic invertebrate communities than site B-2.

The increased diversity at sites B-5 and B-6, compared to site B-2, could be due to water-quality differences such as a continued dilution of high sodium from site M-1. However, the increased levels of trace elements and sulfate concentrations found at B-5 and B-6 would be expected to have a detrimental effect on the compositions of their benthic invertebrate communities. Habitat differences are a more probable reason for the presence of a more impaired community at site B-2. Site B-2 was located at a bridge crossing, and the flow was altered by the bridge, creating a large ponded area upstream and a small riffle area downstream. Site B-5 had a large riffle area with low embeddedness of the substrate and higher velocities, increasing the dissolved oxygen content of the stream. Site B-6 was just upstream from another bridge crossing and had a smaller riffle area than site B-5. Dissolved oxygen concentration measured during the water-quality synoptic survey were lower at site B-2 (5.6 mg/L) than at sites B-5 (7.2 mg/L) and B-6 (7.3 mg/L).

When compared to the ADEM's reference site on Talladega Creek and criteria developed for Appalachian streams for north Alabama, all of the sites sampled in the Big Black Creek Basin are unimpaired to slightly impaired. This would imply that possible effects from the landfill are not pronounced enough to be distinguishable from the effects of coal mining and other activities in the basin. Therefore, the landfill was considered not to have a detrimental effect on the benthic invertebrate communities at the time of the investigation.

SUMMARY AND CONCLUSIONS

Big Black Creek is a tributary to the Cahaba River, a source of drinking water for the City of Birmingham. The Big Black Creek Basin is located in the Valley and Ridge physiographic province in the southwestern corner of St. Clair County, Alabama. Abandoned surface and subsurface coal mines are prevalent throughout the basin.

The geologic structure of the basin is controlled by rock strata that have been extensively faulted and folded. The lithology of the strata is dominantly clastic rock (interbedded sandstone, shales, and coal) of the Pottsville Formation. Ground-water flow moves either as localized flow in the shallow system toward Big Black Creek and its tributaries, or as more complex flow into the deeper, fracture-conduit aquifer. Networks of fractures and joints in the bedrock or abandoned mine shafts serve as pathways or conduits for ground water and can allow the ground water to move downgradient to a deeper flow system.

The Acmar Regional Landfill, located in the Big Black Creek Basin, has been permitted by the Alabama Department of Environmental Management for the disposal of mixed municipal solid waste into lined waste cells that encompass 31 acres. The active waste cells are bordered to the north, east, and west by Big Black Creek.

Synoptic streamflow, water-quality, and biological investigations in the Big Black Creek Basin were conducted by the U.S. Geological Survey in 1997. These investigations obtained data to evaluate the extent that water quality and aquatic organisms are effected by coal-mining or landfill activities in the Big Black Creek Basin.

These investigations were conducted in four parts beginning in April 1997 and ending in August 1997:

(1) Literature review and field reconnaissance to select appropriate sites.

(2) Synoptic survey and assessment of benthic invertebrate communities.

(3) Synoptic streamflow investigation.

(4) Synoptic investigation of stream-water and bed-sediment quality.

Seasonal and annual changes in the streamflow, water quality, and the benthic invertebrate communities in the Big Black Creek Basin can be expected to occur but were not monitored during this study. The effects of landfill activities on water quality in Big Black Creek during high water-table conditions or surface runoff events also were not assessed during this investigation.

The synoptic streamflow investigation was conducted at 28 sites in the basin on August 27, 1997, during a period of base flow to estimate discharge from the ground-water system to the stream and to identify gaining or losing stream reaches. The synoptic streamflow investigation identified two areas of channel loss —between sites S-21 and S-19 on Middle Black Creek and between the confluence of Little Black Creek with Big Black Creek (site B-2) and site B-3, located upstream and upgradient from the Acmar Regional Landfill. Losses in streamflow between these sites may be a result of surface water returning to the ground-water system by flowing through naturally occurring geologic structures or through improperly abandoned shafts and adits associated with subsurface coal mining. Immediately downstream from these reaches of streamflow loss were reaches of significantly greater than normal streamflow gain, suggesting a greater contribution from ground water in these reaches. These gaining stream reaches included those downgradient from the landfill. The distribution of ground-water discharge suggests that if leachate from the landfill migrated to the ground-water system, it would travel relatively short distances before resurfacing as ground-water discharge to the stream.

The synoptic investigation of stream-water and bed-sediment quality was conducted at nine sites during the same period to assess the water-quality conditions in the stream. The results of this investigation identified no distinguishing trend or pattern of contamination that could be attributed solely to landfill activities. No significant increases in chloride levels, specific conductance, total dissolved solids, color, or biochemical oxygen demand were observed at sites downgradient from the landfill. Trace-element and organic compound concentrations in the stream water were below established water-quality standards and criteria for the State of Alabama, with the exception of secondary (aesthetic) drinking-water levels for iron and manganese (Alabama Department of Environmental Management, 1994). Oil and grease concentrations detected in the bed sediments were below the corrective-action limit of 100 mg/kg.

Elevated sulfate and trace-element concentrations were identified at sites B-5 and B-6, which are downstream from the abandoned coal wash and downgradient from the landfill. Based on seepage data, the coal wash could be assumed to exert a greater influence than the landfill on the water quality at these sites.

VOCs were not detected in the stream system, but the detection of 1,1-dichloroethane (the same solvent detected in the ground-water monitoring system at the landfill) in the drive-point well B-4-WL at site B-4 could indicate that the landfill-derived contaminant migrated off site to the stream at extremely low levels (below detectable levels). This drive-point well was located in a stream bank immediately downgradient from the active cells of the landfill. The detection of a known landfill contaminant supports the potential risk of landfill-derived contamination migrating from the landfill to the stream.

A synoptic benthic invertebrate community survey was conducted at four of the nine synoptic water-quality sites to determine community structure and health and to assess the cumulative effects of stream conditions on organisms in the basin. The results of this investigation indicated that the benthic invertebrate communities at sites B-2, B-5, and B-6 had fewer intolerant genera of benthic invertebrates than were at the reference site L-1. Site B-2, upgradient from the landfill, had lower total taxa richness and EPT index than sites B-5 and B-6. Because greater trace-element and sulfate levels were identified at sites B-5 and B-6, habitat differences rather than water-quality difference were considered a more probable reason for the more impaired community at site B-2.

Based on ADEM criteria, all four sites in the Big Black Creek Basin are unimpaired to slightly impaired. This would imply that the landfill did not have a detrimental effect on the benthic invertebrate communities at the time of the study.

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BENTHIC SAMPLING AT SITE B-6, BIG BLACK CREEK NEAR LEEDS, ALA.

APPENDIXES

Appendix 1—Taxa and corresponding tolerance values for organisms found in samples collected from the Big Black Creek Basin, July 16–17, 1997

[ADEM, Alabama Department of Environmental Management; — no value. Benthic invertebrate identification by Pennington Inc., Cookeville, Tenn.]

Taxa	ADEM tolerance values	Site B-6				Site B-5				Site B-3				Site L-1			
		Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total
NEMATODA	6	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
ANNELIDA	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haplotaxida	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naididae	6.1	0	1	0	1	0	0	0	0	0	0	0	0	0	2	0	2
Nais sp.	6.1	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Nais communis	6.1	0	1	0	1	2	0	0	2	0	0	0	0	0	3	10	13
Stylaria lacustris	6.1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Tubificidae w.h.c.	7.1	0	0	0	0	8	0	0	8	3	4	5	12	0	0	0	0
Branchiura sowerbyi	7.1	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0
Tubificidae w.o.h.c.	7.1	10	1	1	12	10	0	0	10	0	2	10	12	0	0	0	0
Lumbricidae	7.1	0	0	0	0	0	0	17	17	5	0	0	5	0	0	0	0
Lumbriculida	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lumbriculidae	7	0	0	9	9	4	0	0	4	25	2	5	32	0	0	0	0
ARTHROPODA	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arachnoidea	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acariformes	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asellidae	8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lirceus sp.	7.9	23	0	1	24	1	0	0	1	0	0	0	0	0	0	0	0
Amphipoda	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Talitridae	7.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hyalella azteca	7.8	3	0	0	3	2	0	0	2	0	0	0	0	0	0	0	0
Decapoda	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cambaridae	6.6	3	0	0	3	10	0	0	10	2	0	0	2	3	0	0	3
Cambarus sp.	7.6	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Insecta	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Collembola	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isotomidae	—	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baetidae	5.7	177	0	1	178	0	0	0	0	48	27	10	85	0	34	10	44
Baetis sp.	4.5	0	7	0	7	39	6	0	45	0	0	0	0	0	0	51	51
Baetis intercalaris	4.5	0	8	54	62	2	10	103	115	24	90	125	239	0	0	30	30
Centroptilum sp.	6.6	0	0	0	0	0	0	0	0	0	0	0	0	66	22	0	88
Caenidae	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caenis sp.	7.4	0	0	0	0	1	0	0	1	0	0	0	0	0	2	0	2
Ephemeridae	3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hexagenia sp.	4.9	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0

Appendix 1—Taxa and corresponding tolerance values for organisms found in samples collected from the Big Black Creek Basin, July 16–17, 1997—Continued

[ADEM, Alabama Department of Environmental Management; — no value. Benthic invertebrate identification by Pennington Inc., Cookeville, Tenn.]

Taxa	ADEM tolerance values	Site B-6				Site B-5				Site B-3				Site L-1			
		Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total
Heptageniidae	4	0	0	2	2	0	3	53	56	2	7	30	39	0	15	30	45
Leucrocuta sp.	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	60
Stenacron interpunctatum	3.6	14	5	1	20	4	4	3	11	0	4	10	14	4	6	0	10
Stenonema sp.	3.5	0	0	29	29	9	0	0	9	0	0	0	0	0	0	20	20
Stenonema femoratum	3.5	0	0	1	1	0	1	0	1	0	1	26	27	1	11	10	22
Stenonema modestum	3.5	38	3	0	41	0	12	80	92	43	104	275	422	63	18	0	81
Isonychiidae	3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isonychia sp.	3.5	0	0	9	9	0	0	16	16	0	3	26	29	0	0	0	0
Leptophlebiidae	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	5
Choroterpes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Paraleptophlebia sp.	0.9	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	13
Tricorythidae	5.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tricorythodes sp.	5.1	7	0	0	7	1	0	0	1	0	0	0	0	0	0	0	0
Odonata	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zygoptera	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calopterygidae	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calopteryx sp.	7.8	3	0	0	3	4	0	0	4	1	0	0	1	19	1	0	20
Coenagrionidae	7.2	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0
Argia sp.	8.2	0	0	0	0	3	0	0	3	2	0	0	2	0	0	0	0
Enallagma sp.	8.9	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Anisoptera	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aeshnidae	6.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boyeria sp.	6	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
Boyeria vinosa	6	3	0	0	3	4	0	0	4	1	3	0	4	13	2	0	15
Macromiidae	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macromia sp.	6.2	1	0	0	1	4	1	0	5	5	0	0	5	2	0	0	2
Gomphidae	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dromogomphus sp.	5.9	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Gomphus sp.	5.8	4	0	0	4	11	0	0	11	4	0	0	4	1	0	0	1
Hagenius brevistylus	4	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Libellulidae	9.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Libellula sp.	9.6	0	0	0	0	0	0	0	0	2	0	0	2	4	0	0	4
Plecoptera	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Perlidae	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acroneuria abnormis	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Heteroptera	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gerridae	—	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
Veliidae	—	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
Rhagovelia obesa	—	0	0	0	0	0	0	0	0	2	2	0	4	0	0	0	0

Appendix 1—Taxa and corresponding tolerance values for organisms found in samples collected from the Big Black Creek Basin, July 16–17, 1997—Continued

[ADEM, Alabama Department of Environmental Management; — no value. Benthic invertebrate identification by Pennington Inc., Cookeville, Tenn.]

Taxa	ADEM tolerance values	Site B-6				Site B-5				Site B-3				Site L-1			
		Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total
Megaloptera	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corydalidae	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corydalus cornutus	5.2	0	0	1	1	0	0	8	8	0	0	1	1	0	0	1	1
Nigronia serricornis	5.3	0	0	14	14	0	0	10	10	3	1	25	29	2	0	0	2
Sialidae	7.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sialis sp.	7.2	0	0	0	0	16	0	0	16	6	1	0	7	20	3	0	23
Trichoptera	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachycentridae	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrasema sp.	0.6	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Calamoceratidae	2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anisocentropus pyraloides	0.9	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	3
Glossosomatidae	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Glossosoma sp.	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Hydropsychidae	3.1	0	0	0	0	0	1	43	44	0	1	5	6	0	0	0	0
Ceratopsyche morosa	1.3	0	0	1	1	0	0	3	3	0	0	0	0	0	0	0	0
Cheumatopsyche sp.	6.2	0	0	26	26	0	6	54	60	0	5	10	15	0	2	40	42
Hydropsyche sp.	4.3	0	6	1	7	0	0	3	3	0	0	5	5	0	0	0	0
Potamyia flava	4	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Hydroptilidae	3.1	0	0	2	2	0	0	0	0	0	0	0	0	0	0	10	10
Hydroptila sp.	6.2	0	8	2	10	0	0	17	17	0	1	5	6	0	1	2	3
Oxyethira sp.	2.2	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Leptoceridae	3.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oecetis sp.	4.7	3	2	0	5	0	0	0	0	0	1	10	11	0	0	0	0
Triaenodes sp.	4.5	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0
Limnephilidae	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydatophylax argus	2.2	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	3
Pycnopsyche sp.	2.5	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Philopotamidae	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chimarra sp.	2.8	0	0	4	4	0	0	3	3	0	0	0	0	0	0	0	0
Polycentropodidae	4.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyrnellus fraternus	7.3	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	7
Polycentropus sp.	3.5	7	0	0	7	30	0	0	30	7	1	0	8	7	1	0	8
Psychomyiidae	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lype diversa	4.1	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	22
Coleoptera	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chrysomelidae	4	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Coccinellidae	—	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Dryopidae	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Helichus basalis	4.6	0	0	0	0	0	0	0	0	0	0	0	0	1	0	10	11

Appendix 1—Taxa and corresponding tolerance values for organisms found in samples collected from the Big Black Creek Basin, July 16–17, 1997—Continued

[ADEM, Alabama Department of Environmental Management; — no value. Benthic invertebrate identification by Pennington Inc., Cookeville, Tenn.]

Taxa	ADEM tolerance values	Site B-6				Site B-5				Site B-3				Site L-1			
		Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total
Dytiscidae	6	0	0	0	0	2	0	0	2	1	1	0	2	17	0	0	17
Agabetes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	46	0	0	46
Hydroporus sp.	8.6	0	0	0	0	7	0	0	7	1	0	0	1	6	0	0	6
Laccophilus sp.	10	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	3
Elmidae	3.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ancyronyx variegata	6.5	3	1	0	4	12	0	3	15	1	26	10	37	0	0	0	0
Dubiraphia sp.	5.9	0	0	0	0	0	0	0	0	0	1	0	1	21	0	0	21
Dubiraphia quadrinotata	5.9	23	4	0	27	58	1	0	59	2	5	5	12	50	11	1	62
Macronychus glabratus	4.6	3	1	1	5	14	0	0	14	7	17	5	29	2	0	0	2
Microcylloepus pusillus	2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Optioservus sp.	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	20
Promoresia elegans	2.4	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
Stenelmis sp.	5.1	0	0	0	0	0	0	0	0	0	0	10	10	0	0	10	10
Gyrinidae	5.8	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
Dineutus sp.	5.5	3	0	0	3	0	0	0	0	0	0	0	0	3	0	0	3
Gyretes sp.	5.8	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	1
Haliplidae	8.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peltodytes sp.	8.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	5.3	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Sperchopsis tessellatus	6.1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
Tropisternus sp.	9.7	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Psephenidae	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Psephenus herricki	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
Scirtidae	6	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Staphylinidae	6	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae	6.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bezzia/Palpomyia gp.	6.9	0	0	0	0	1	1	0	2	0	0	0	0	0	0	0	0
Chironomidae	—	10	12	2	24	9	1	30	40	4	2	15	21	16	19	130	165
Ablabesmyia sp.	7.2	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
Ablabesmyia mallochi	7.2	40	4	0	44	23	2	3	28	15	1	0	16	52	0	2	54
Brillia flavifrons	5.2	0	0	0	0	0	0	0	0	0	4	0	4	2	0	0	2
Cardiocladius obscurus	5.9	0	0	1	1	0	1	7	8	0	0	0	0	0	0	0	0
Cladopelma sp.	3.5	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Corynoneura sp.	6	0	1	0	1	0	0	0	0	0	0	0	0	0	0	5	5
Cricotopus sp.	5.8	3	26	3	32	7	5	80	92	0	3	10	13	0	5	17	22
Cricotopus bicinctus	5.8	0	2	1	3	2	2	30	34	1	0	10	11	0	0	5	5
Cricotopus tremulus	5.8	0	1	4	5	0	6	130	136	0	0	0	0	0	2	24	26
Cryptochironomus fulvus	6.4	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1—Taxa and corresponding tolerance values for organisms found in samples collected from the Big Black Creek Basin, July 16–17, 1997—Continued

[ADEM, Alabama Department of Environmental Management; — no value. Benthic invertebrate identification by Pennington Inc., Cookeville, Tenn.]

Taxa	ADEM tolerance values	Site B-6				Site B-5				Site B-3				Site L-1			
		Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total
Dicrotendipes	8.1	0	1	0	1	0	0	0	0	0	1	0	1	0	0	0	0
Eukiefferiella claripennis	3.4	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0
Eukiefferiella devonica gp.	3.4	0	0	1	1	0	1	3	4	0	0	0	0	0	0	0	0
Labrundinia sp.	5.9	17	0	0	17	0	0	0	0	2	0	0	2	11	0	0	11
Larsia sp.	9.3	10	0	0	10	12	0	0	12	0	0	0	0	2	0	0	2
Microchironomus sp.	—	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
Microtendipes sp.	5.5	0	0	0	0	0	1	0	1	0	0	0	0	36	10	8	54
Nanocladius sp.	7.1	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Nilothauma sp.	5	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
Parakiefferiella sp.	5.4	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Parametriocnemus lundbecki	3.7	3	0	0	3	0	0	0	0	0	0	5	5	0	0	8	8
Paratendipes sp.	5.1	7	0	0	7	0	0	0	0	1	0	0	1	4	8	0	12
Pentaneura sp.	4.7	7	1	0	8	34	1	0	35	6	1	0	7	4	0	0	4
Polypedilum sp.	5.8	0	1	0	1	4	0	0	4	0	0	0	0	0	0	0	0
Polypedilum convictum	5.8	0	0	1	1	0	0	3	3	0	0	5	5	0	0	5	5
Polypedilum fallax	5.8	0	0	0	0	0	0	0	0	0	2	0	2	0	13	0	13
Polypedilum halterale	5.8	3	0	0	3	21	0	0	21	0	1	0	1	4	0	0	4
Polypedilum illinoense	5.8	30	0	1	31	0	6	3	9	23	7	25	55	19	0	5	24
Pseudochironomus sp.	5.4	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Rheocricotopus robacki	7.3	3	16	2	21	0	1	17	18	6	11	5	22	4	13	16	33
Rheotanytarsus sp.	5.9	10	7	180	197	10	1	70	81	5	22	65	92	8	99	48	155
Stenochironomus sp.	6.5	3	1	0	4	0	0	0	0	1	1	0	2	0	0	0	0
Tanytarsus sp.	6.8	30	27	0	57	12	3	7	22	4	7	0	11	4	61	5	70
Thienemanniella xena	5.9	3	0	1	4	0	0	0	0	0	0	0	0	0	5	5	10
Thienemannimyia sp. gp.	6.2	10	1	1	12	21	1	3	25	6	4	5	15	25	8	5	38
Tribelos sp.	6.3	67	0	0	67	25	0	0	25	0	0	0	0	21	15	0	36
Tvetenia discoloripes sp. gp.	3.6	0	1	1	2	0	1	3	4	0	0	0	0	0	0	0	0
Xylotopus par	6	3	0	0	3	0	0	0	0	2	0	0	2	0	2	0	2
Zavrelia sp.	5.3	0	0	0	0	0	0	0	0	0	0	0	0	8	13	3	24
Culicidae	8.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anopheles sp.	8.6	0	0	0	0	0	0	0	0	7	0	5	12	37	4	0	41
Dixidae	2.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dixa sp.	2.6	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	5
Dixella sp.	2.6	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
Empididae	7.6	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
Chelifera sp.	7.6	0	0	0	0	0	0	3	3	0	0	0	0	0	1	0	1
Hemerodromia sp.	7.6	0	2	1	3	0	1	17	18	0	1	5	6	0	2	30	32
Psychodidae	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pericoma sp.	4	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0

Appendix 1—Taxa and corresponding tolerance values for organisms found in samples collected from the Big Black Creek Basin, July 16–17, 1997—Continued

[ADEM, Alabama Department of Environmental Management; — no value. Benthic invertebrate identification by Pennington Inc., Cookeville, Tenn.]

Taxa	ADEM tolerance values	Site B-6				Site B-5				Site B-3				Site L-1			
		Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total	Root/ bank	Log/ rock	Riffle	Total
Simuliidae	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Simulium sp.	4	0	0	16	16	0	50	30	80	3	24	105	132	1	1	10	12
Tipulidae	5.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Antocha sp.	4.3	0	0	0	0	0	0	3	3	0	0	5	5	0	0	190	190
Hexatoma sp.	4.3	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0
Limnophila sp.	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
Tipula sp.	7.3	3	0	0	3	1	0	0	1	0	0	0	0	1	0	0	1
MOLLUSCA	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bivalvia	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Veneroida	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corbiculidae	6.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corbicula fluminea	6.1	0	1	44	45	0	0	11	11	0	0	16	16	1	0	0	1

Appendix 2—Schedule 1380: Analysis of an unfiltered water sample for 61 volatile organic compounds with a minimum reporting level (MRL) of 0.2 microgram per liter (µg/L)

Parameter code	CAS no.	Volatile organic compound	MRL	Unit
77562	630-20-6	1,1,1,2-Tetrachloroethane	0.2	µg/L
34506	71-55-6	1,1,1-Trichloroethane	0.2	µg/L
34516	79-34-5	1,1,2,2-Tetrachloroethane	0.2	µg/L
34511	79-00-5	1,1,2-Trichloroethane	0.2	µg/L
77652	76-13-1	1,1,2-Trichlorotrifluoroethane	0.2	µg/L
34496	75-34-3	1,1-Dichloroethane	0.2	µg/L
34501	75-35-4	1,1-Dichloroethylene	0.2	µg/L
77168	563-58-6	1,1-Dichloropropene	0.2	µg/L
77613	87-61-6	1,2,3-Trichlorobenzene	0.2	µg/L
77443	96-18-4	1,2,3-Trichloropropane	0.2	µg/L
34551	120-82-1	1,2,4-Trichlorobenzene	0.2	µg/L
77222	95-63-6	1,2,4-Trimethylbenzene	0.2	µg/L
82625	96-12-8	1,2-Dibromo-3-chloropropane	1	µg/L
77651	106-93-4	1,2-Dibromoethane	0.2	µg/L
34536	95-50-1	1,2-Dichlorobenzene	0.2	µg/L
32103	107-06-2	1,2-Dichloroethane	0.2	µg/L
99832	17060-07-0	1,2-Dichloroethane-d4 (surrogate)	0.1	percent
34541	78-87-5	1,2-Dichloropropane	0.2	µg/L
77226	108-67-8	1,3,5-Trimethylbenzene	0.2	µg/L
34566	541-73-1	1,3-Dichlorobenzene	0.2	µg/L
77173	142-28-9	1,3-Dichloropropane	0.2	µg/L
99834	460-00-4	1,4-Bromofluorobenzene (surrogate)	0.1	percent
34571	106-46-7	1,4-Dichlorobenzene	0.2	µg/L
77170	594-20-7	2,2-Dichloropropane	0.2	µg/L
34576	110-75-8	2-Chloroethylvinylether	1	µg/L
77275	95-49-8	2-Chlorotoluene	0.2	µg/L
77277	106-43-4	4-Chlorotoluene	0.2	µg/L
77356	99-87-6	4-Isopropyl-1-methylbenzene	0.2	µg/L
34030	71-43-2	Benzene	0.2	µg/L
81555	108-86-1	Bromobenzene	0.2	µg/L
77297	74-97-5	Bromochloromethane	0.2	µg/L
32101	75-27-4	Bromodichloromethane	0.2	µg/L
32104	75-25-2	Bromoform	0.2	µg/L
34413	74-83-9	Bromomethane	0.2	µg/L
77342	104-51-8	Butylbenzene	0.2	µg/L
34301	108-90-7	Chlorobenzene	0.2	µg/L
34311	75-00-3	Chloroethane	0.2	µg/L
32106	67-66-3	Chloroform	0.2	µg/L
34418	74-87-3	Chloromethane	0.2	µg/L
77093	156-59-2	cis-1,2-Dichloroethylene	0.2	µg/L

Appendix 2—Schedule 1380: Analysis of an unfiltered water sample for 61 volatile organic compounds with a minimum reporting level (MRL) of 0.2 microgram per liter (µg/L)—Continued

Parameter code	CAS no.	Volatile organic compound	MRL	Unit
34704	10061-01-5	cis-1,3-Dichloropropene	0.2	µg/L
32105	124-48-1	Dibromochloromethane	0.2	µg/L
30217	74-95-3	Dibromomethane	0.2	µg/L
34668	75-71-8	Dichlorodifluoromethane	0.2	µg/L
34423	75-09-2	Dichloromethane	0.2	µg/L
34371	100-41-4	Ethylbenzene	0.2	µg/L
39702	87-68-3	Hexachlorobutadiene	0.2	µg/L
77223	98-82-8	Isopropylbenzene	0.2	µg/L
34696	91-20-3	Naphthalene	0.2	µg/L
77224	103-65-1	Propylbenzene	0.2	µg/L
77350	135-98-8	sec-Butylbenzene	0.2	µg/L
77128	100-42-5	Styrene	0.2	µg/L
78032	1634-04-4	tert-Butyl methyl ether	0.2	µg/L
77353	98-06-6	tert-Butylbenzene	0.2	µg/L
34475	127-18-4	Tetrachloroethylene	0.2	µg/L
32102	56-23-5	Tetrachloromethane	0.2	µg/L
34010	108-88-3	Toluene	0.2	µg/L
99833	2037-26-5	Toluene-d8 (surrogate)	0.1	percent
34546	156-60-5	trans-1,2-Dichloroethylene	0.2	µg/L
34699	10061-02-6	trans-1,3-Dichloropropene	0.2	µg/L
39180	79-01-6	Trichloroethylene	0.2	µg/L
34488	75-69-4	Trichlorofluoromethane	0.2	µg/L
39175	75-01-4	Vinyl chloride	0.2	µg/L
81551	1330-20-7	Xylene	0.2	µg/L

CONVERSION FACTORS AND TEMPERATURE

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter
	Area	
acre	4,047	square meter
	0.4047	hectare
square mile (mi^2)	2.590	square kilometer
	Volume	
gallon (gal)	3.785	liter
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per square mile ($[ft^3/s]/mi^2$)	0.01093	cubic meter per second per square kilometer
ton per day per square mile ($[ton/d]/mi^2$)	0.3503	megagram per day per square kilometer

TEMPERATURE: In this report, temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F = 1.8 (°C + 32)$$