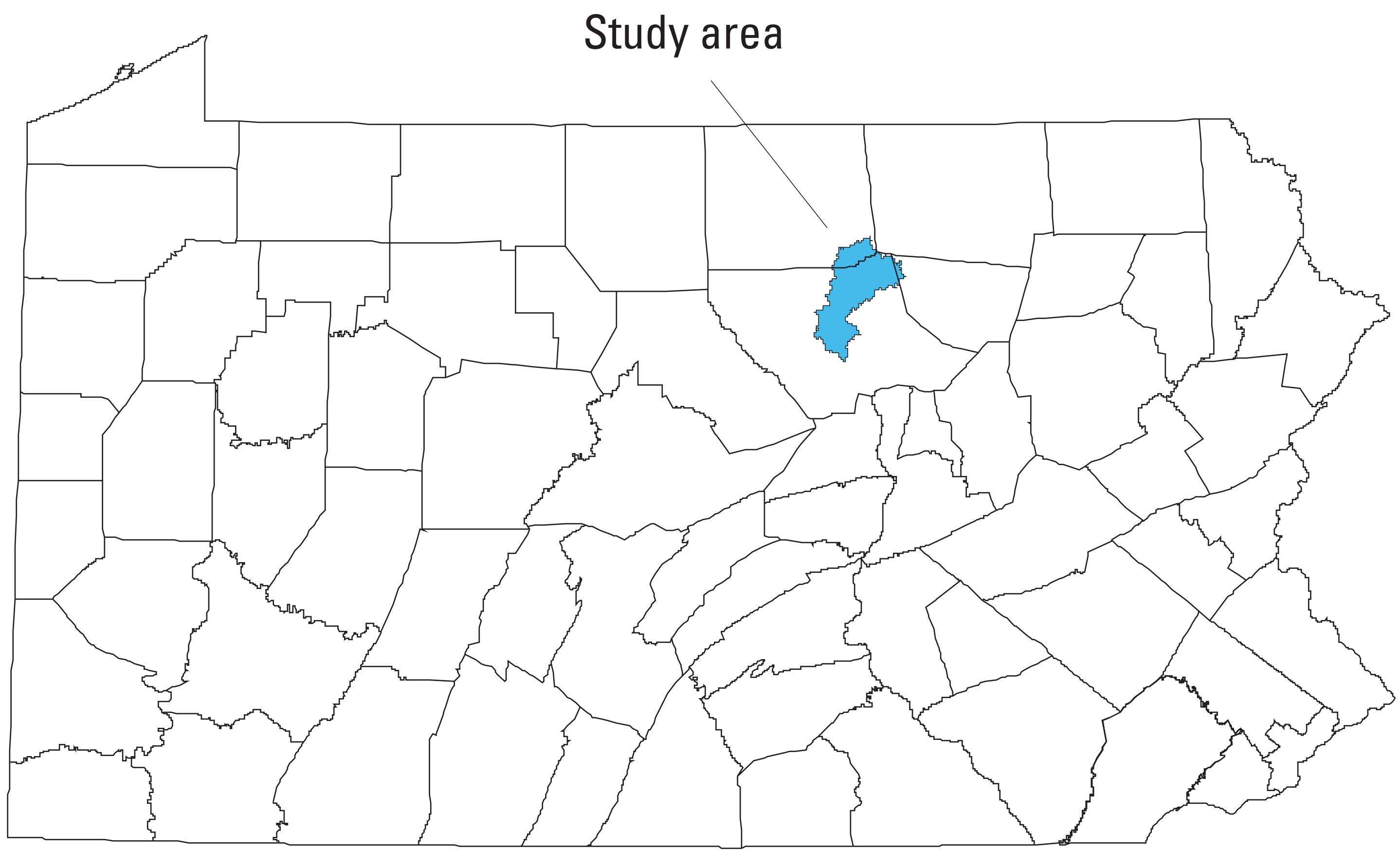
Prepared in cooperation with the Williamsport Municipal Water Authority

Surface-Water Quality in the Lycoming Creek Watershed, North-Central Pennsylvania, August 1–3, 2011



Scientific Investigations Report 2017–5154

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

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By Dennis W. Risser and Matthew D. Conlon

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RYAN K. ZINKE, Secretary

U.S. Geological Survey
James F. Reilly II, Director

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
	Pressure	
inch of mercury at 60 ºF (in Hg)	3.377	kilopascal (kPa)
pound per square inch (lb/in^2)	6.895	kilopascal (kPa)
	Radioactivity	
picocurie per liter (pCi/L)	0.037	becquerel per liter (Bq/L)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8×°C)+32.$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8.$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Surface-Water Quality in the Lycoming Creek Watershed, North-Central Pennsylvania, August 1–3, 2011

By Dennis W. Risser and Matthew D. Conlon

Abstract

This report presents the methodology and results for a study of surface-water quality of the Lycoming Creek watershed in north-central Pennsylvania during August 1–3, 2011. The study was done in cooperation with the Williamsport Municipal Water Authority and the Pennsylvania Department of Environmental Protection. Samples of stream water were collected from 31 sites in an area of exploration and production of natural gas from the Marcellus Shale – 5 sites on the main stem of Lycoming Creek and 26 sites on tributary streams. The samples provide a snapshot of the base-flow water-quality conditions, which helps document the spatial variability in water-quality and could be useful for assessing future changes.

The 272-square mile Lycoming Creek watershed is located within Lycoming, Tioga, and Sullivan Counties in north-central Pennsylvania. Lycoming Creek flows 37.5 miles to its confluence with the West Branch Susquehanna River in the city of Williamsport. A well field that supplies water for Williamsport captures some water that has infiltrated the streambed of Lycoming Creek. Because the stream provides a source of water to the well field, this study focused on the stream-water quality as it relates to drinking-water standards as opposed to aquatic life.

Surface-water samples collected at 20 sites by the U.S. Geological Survey and 11 sites by the Pennsylvania Department of Environmental Protection were analyzed by each agency for a suite of constituents that included major ions, trace metals, nutrients, and radiochemicals. None of the analytical results failed to meet standards set by the U.S. Environmental Protection Agency as maximum contaminant levels for drinking water.

Results of the sampling show the substantial spatial variability in base-flow water quality within the Lycoming Creek watershed caused by the interrelated effects of physiography, geology and land use. Dissolved-solids concentrations ranged from less than the laboratory reporting level of 12 milligrams per liter (mg/L) in Wolf Run, a pristine forested watershed, to 202 mg/L in Bottle Run, a watershed with more development near Williamsport. Concentrations of the major ions ranged over at least one order of magnitude; chloride had the largest range from 0.3 to 45.4 mg/L, with nine samples exceeding the natural background level of about 5 mg/L, most likely because of the application of deicing salt to roads. Trace constituents were even more variable, with concentrations for aluminum, cobalt, and manganese ranging over almost four orders of magnitude. Samples from Red Run and Dutchman Run, watersheds that experienced past coal mining activity, had concentrations of 11 metals that were significantly greater than in samples collected from other streams. Samples from Bottle Run, the tributary of Lycoming Creek nearest to Williamsport, contained elevated levels of chloride and boron, constituents associated with urban development.

Introduction

The Williamsport Municipal Water Authority (WMWA) is the public water supplier for about 50 percent of the population of Lycoming County. During periods of low streamflow, WMWA supplements its surface-water sources located south of the West Branch Susquehanna River with groundwater from a well field in the city of Williamsport near Lycoming Creek. The nine shallow production wells in the Lycoming Creek well field withdraw water from the alluvial sand-and-gravel aquifer. Infiltration induced from Lycoming Creek is a source of recharge to the alluvial deposits that is captured by the production wells (Spotts, Stevens, McCoy, 2009). Thus, the quality of groundwater withdrawn by the wells can be affected by the chemical composition of water in the creek. In turn, the quality of water in Lycoming Creek can be affected by land-use activities within the watershed.

Current or past land-use activities in Lycoming Creek watershed include agriculture, silviculture, aquiculture, urban development, and mining, but the most notable recent activity is related to extraction of natural gas from the Marcellus Shale. The first Marcellus Shale gas well in Lycoming Creek watershed was drilled in July 2007, and by August 1, 2011, sixty-five wells had been drilled at 38 pads in the watershed on both private and public lands (Pennsylvania Department of Environmental Protection, 2016a). During that time, briny wastewater from some gas wells in Pennsylvania was being transported to sewage-treatment facilities (outside of the Lycoming Creek watershed), where the water was treated with conventional techniques and diluted with the conventional wastewater before being discharged to Pennsylvania streams (Abdalla and others, 2011). That disposal practice, along with land disturbances from access roads, gas wells, and pipeline construction, caused the WMWA to have concerns about the possible effects of shale-gas development on the quality of water in Lycoming Creek. Because of that concern, WMWA asked the U.S. Geological Survey (USGS) to collect water samples in Lycoming Creek and its tributaries to provide information about water-quality conditions that could be used to assess future changes.

Purpose and Scope

This report describes the methods and results of a study, in cooperation with the WMWA and Pennsylvania Department of Environmental Protection (PaDEP), to survey the quality of water in Lycoming Creek and its tributary streams. The purpose of the study was to establish data on base-flow water quality for a broad set of chemical constituents that could provide a basis for distinguishing contaminants from various land-use activities such as natural-gas development, road maintenance, agricultural operations, and urbanization.

The quality of surface water throughout the watershed was documented with a single reconnaissance survey by collecting water samples at 31 sites on the main stem of Lycoming Creek and its tributary streams during base-flow conditions August 1–3, 2011 (fig. 1 and table 1). The samples were analyzed for field constituents, major ions, nutrients, trace metals, and radiochemicals. The results provide a snapshot of water quality during that single base-flow condition. The concentrations of the water-quality constituents found in water samples from streams are presented and compared against U.S. Environmental Protection Agency (EPA) drinking-water standards or health-based screening levels. Differences in water chemistry throughout the watershed are discussed in relation to geology and land use. Quality-assurance samples are discussed to evaluate possible errors introduced by contamination in the field, sampling methods, and different laboratories used to analyze the samples. Data are presented in tables; data also are available online through the USGS National Water Information System (NWIS) (U.S. Geological Survey, 2017), and can be accessed by using the station identifiers in table 1.

Study Area

Lycoming Creek watershed covers 272 square miles (mi^2) in Lycoming, Tioga, and Sullivan Counties in north-central Pennsylvania (fig. 1). From its headwaters in northern Lycoming County, Lycoming Creek flows 37.5 miles to its confluence with West Branch Susquehanna River in Williamsport. The Lycoming Creek well field is near the confluence. The diversity in physiography, geology, land use, and hydrologic setting within the watershed all influence the quality of water flowing past the well field.

Physiography and Geology

The Lycoming Creek watershed is situated within the Ridge and Valley and Appalachian Plateaus Physiographic Provinces (fig. 2). The southern part of the watershed (about 16 percent) lies within the Susquehanna Lowland Section of the Ridge and Valley Province (Sevon, 2000), which is characterized in this area by low to moderate relief developed mostly on shale, siltstone, and sandstone of Devonian age. The majority of the watershed (about 84 percent) is situated within three different sections of the Appalachian Plateaus Physiographic Province—the Deep Valleys Section, Glaciated Low Plateau Section, and Glaciated High Plateau Section. The Deep Valleys and Glaciated High Plateau sections compose the middle part of the watershed, which is characterized by steep relief, deep valleys, and broad to narrow ridges capped by sandstones of Mississippian and Pennsylvanian age. The Glaciated Low Plateau Section and a small sliver of the Glaciated High Plateau Section compose the northern part of the watershed. The Glaciated Low Plateau section is characterized by rounded hills and broad valleys of low relief carved into shale, siltstone, and sandstone of Devonian age.

Land-surface altitudes range widely across the watershed. The highest altitude is about 2,380 feet on the watershed boundary in Sullivan County within the Glaciated High Plateau Section of the Appalachian Plateaus Province; the lowest is about 510 feet at the confluence of Lycoming Creek and the West Branch Susquehanna River within the Susquehanna Lowland Section of the Valley and Ridge Province.

Lycoming Creek watershed is underlain by clastic bedrock units of Devonian, Mississippian, and Pennsylvanian age consisting predominantly of siltstone, shale, and sandstone, with some coal. The bedrock geologic units, as shown on the geologic map of Pennsylvania (Miles and Whitfield, 2001) from oldest to youngest are the Old Port Formation, Onondaga Formation, Hamilton Group, Brallier Formation, Harrell Formation, Lock Haven Formation, and Catskill Formation of Devonian age; the Huntley Mountain Formation of Devonian and Mississippian ages; the Burgoon Sandstone and Mauch Chunk Formation of Mississippian age; and the Pottsville and Allegheny Formations of Pennsylvanian age (fig. 3 and table 2). The Onondaga and Old Port Formations are not included on figure 3 and table 2 because their outcrop areas, at the confluence of Lycoming Creek and West Branch Susquehanna River, are too small to be shown. The bedrock units are considered aquifers because all are capable of producing adequate quantities of water for domestic use, though adequate yields for public supply are less reliable.

Glaciers covered the entire watershed during the pre-Illinoian Stage and about two-thirds of the watershed during the latest glacial advance, the Wisconsinan Stage. The south boundary of the Wisconsinan glaciation is shown in figure 3 (Sevon and Braun, 2000). Glaciers deposited a thin mantel of glacial till on the uplands, and stratified sand and gravel deposits predominantly along the main stem of Lycoming

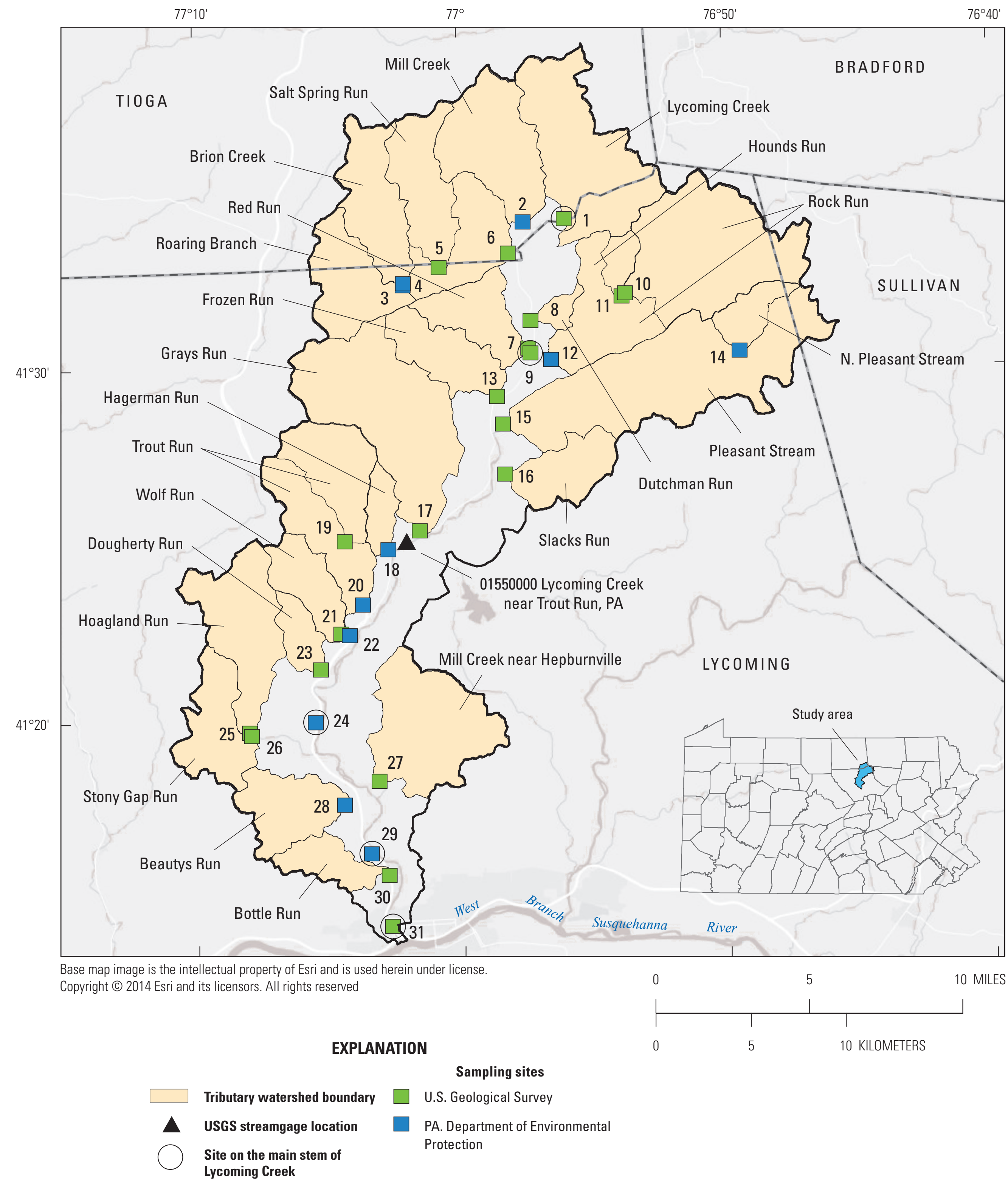


Figure 1. Location of the Lycoming Creek watershed in north-central Pennsylvania and sites where surface-water samples were collected during August 1–3, 2011, by personnel from the U.S. Geological Survey and Pennsylvania Department of Environmental Protection. See table 1 for key to station numbers.

Table 1. Sites where surface water was sampled by USGS and PaDEP in the Lycoming Creek watershed in north-central Pennsylvania, August 1–3, 2011.

[ID, identifier; PA, Pennsylvania; USGS, U.S. Geological Survey; PaDEP, Pennsylvania Department of Environmental Protection; NAD, North American Datum of 1983; mi², square miles; St., street; dark shading indicates site on main stem of Lycoming Creek; --, no data]

Map ID	USGS station ID	USGS site name	Latitude NAD83. (decimal degrees)	Longitude NAD83 (decimal degrees)	Agency collecting environ-mental sample	PaDEP ID	Basin area (mi²)
1	01549895	Lycoming Creek near Dogtown, PA	41.5704	-76.9300	USGS	--	15.6
2	01549898	Mill Creek upstream of Roaring Branch, PA	41.5692	-76.9558	PaDEP	MC 2.5	11.0
3	015499012	Roaring Branch upstream of Brion Creek near South Union, PA	41.5397	-77.0319	PaDEP	RB 1	7.8
4	015499011	Brion Creek near South Union, PA	41.5403	-77.0317	PaDEP	BC 1.5	8.1
5	015499015	Salt Spring Run near South Union, PA	41.5478	-77.0092	USGS	--	7.6
6	015499001	[1]Roaring Branch near Roaring Branch, PA	41.5543	-76.9655	USGS	RB 2	30.5
7	01549903	Red Run at Ralston, PA	41.5092	-76.9533	USGS	--	5.7
8	015499027	Dutchman Run near Ralston, PA	41.5223	-76.9517	USGS	--	1.1
9	01549904	[1]Lycoming Creek at Ralston, PA	41.5072	-76.9517	USGS	LC 4	71.6
10	015499055	Rock Run at McIntyre Township, PA	41.5349	-76.8920	USGS	--	18.0
11	015499056	Hounds Run at McIntyre Township, PA	41.5336	-76.8942	USGS	--	1.7
12	015499068	Rock Run upstream of Lycoming Creek near Ralston, PA	41.5039	-76.9392	PaDEP	RR 5	27.7
13	01549909	Frozen Run near Ralston, PA	41.4867	-76.9733	USGS	--	6.3
14	01549920	North Pleasant Stream at Masten, PA	41.5072	-76.8206	PaDEP	NPS 6.5	3.0
15	01549930	[1]Pleasant Stream at Marsh Hill, PA	41.4738	-76.9697	USGS	PS 6	26.8
16	01549950	Slacks Run at Bodines, PA	41.4501	-76.9687	USGS	--	5.7
17	01549990	[1]Grays Run near Fields Station, PA	41.4238	-77.0226	USGS	GR 7	19.7
18	01550010	Hagerman Run near Trout Run, PA	41.4150	-77.0425	PaDEP	HR 7.5	2.4
19	01550100	Trout Run at Route 15 at Lewis Township, PA	41.4190	-77.0698	USGS	--	7.4
20	01550150	Trout Run upstream of Lycoming Creek at Trout Run, PA	41.3889	-77.0589	PaDEP	TR 8	14.5
21	01550200	Wolf Run near Trout Run, PA	41.3752	-77.0727	USGS	--	5.0
22	01550205	Wolf Run upstream of Lycoming Creek near Trout Run, PA	41.3744	-77.0672	PaDEP	WR 8.5	5.0
23	01550250	Daugherty Run near Powys, PA	41.3584	-77.0856	USGS	--	2.8
24	01550260	Lycoming Creek at Haleeka, PA	41.3336	-77.0892	PaDEP	LC 9	210
25	01550300	Hoagland Run near Quiggleville, PA	41.3289	-77.1306	USGS	--	10.7
26	01550305	Stoney Gap Run near Quiggleville, PA	41.3275	-77.1293	USGS	--	7.3
27	01550350	[1]Mill Creek near Hepburnville, PA	41.3055	-77.0498	USGS	MC 10	13.5
28	01550380	Beautys Run near Hepburnville, PA	41.2944	-77.0717	PaDEP	BR 10.5	6.9
29	01550390	Lycoming Creek near Heshbon Park, PA	41.2714	-77.0550	PaDEP	LC 11	263
30	01550505	Bottle Run near Williamsport, PA	41.2611	-77.0439	USGS	--	3.9
31	01550600	Lycoming Creek at 3rd St. bridge at Williamsport, PA	41.2370	-77.0423	USGS	--	272

[1]Site where quality-assurance samples were collected by USGS and PaDEP personnel to evaluate the effects of different sample-collection protocols and laboratories.

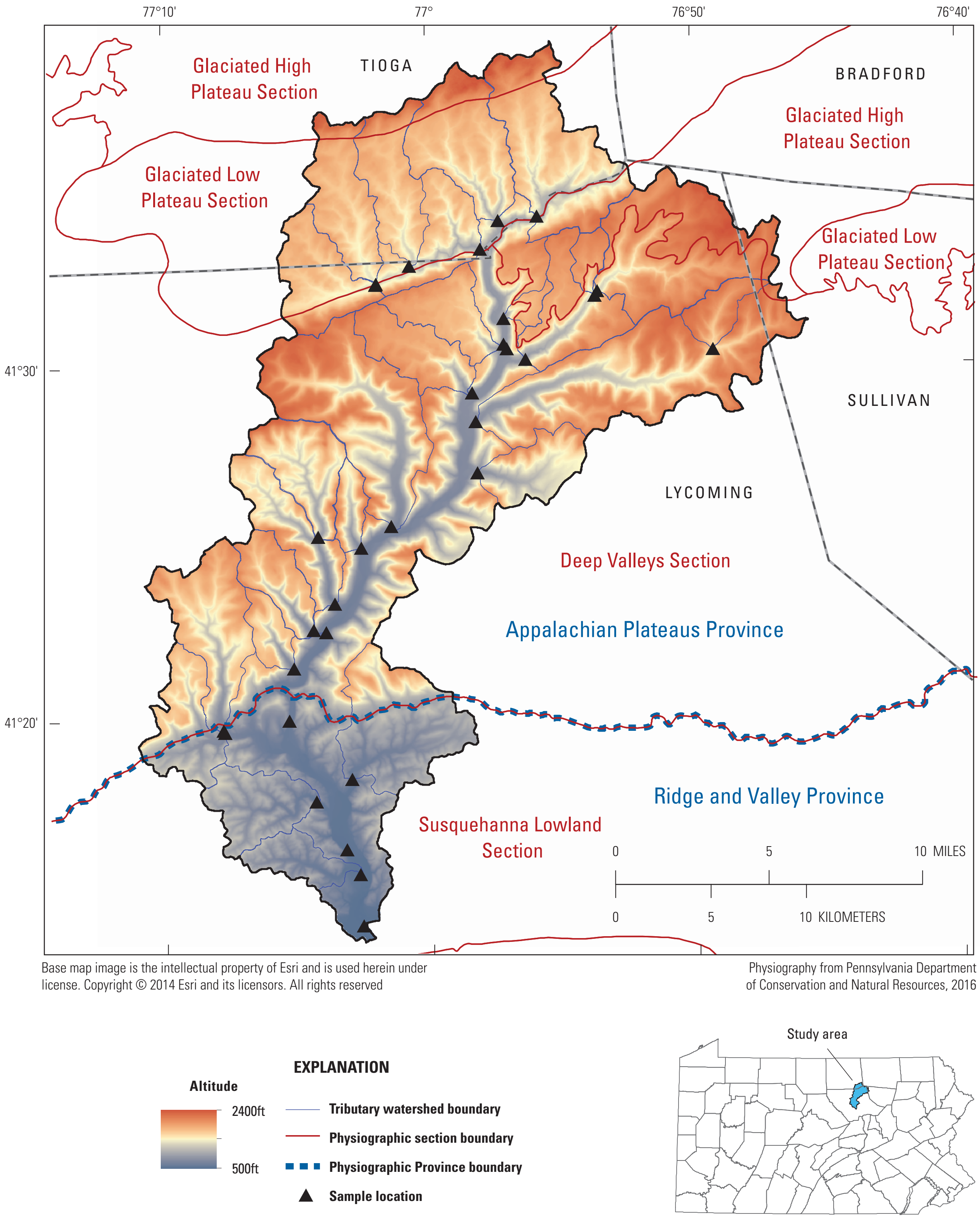


Figure 2. Physiographic setting of the Lycoming Creek watershed in north-central Pennsylvania.

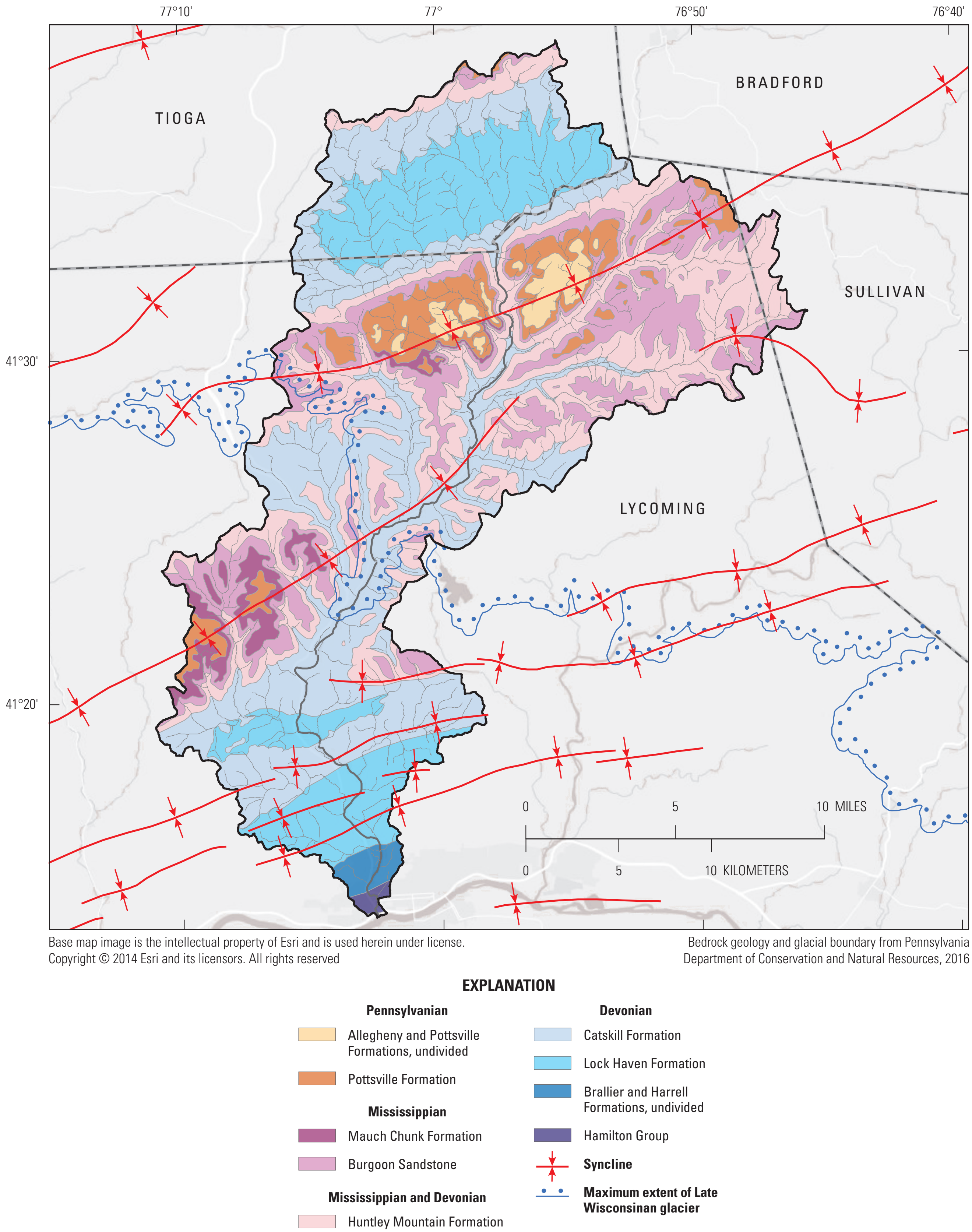


Figure 3. Bedrock geology of the Lycoming Creek watershed in north-central Pennsylvania.

Table 2. Bedrock geologic units upstream of each sampling station in the Lycoming Creek watershed, north-central Pennsylvania.

[USGS, U.S. Geological Survey; St., street; --, no data]

Map identifier	USGS station name	Percent of basin area (shaded where value exceeds 25 percent)							
		Allegheny and Pottsville Formations[1]	Mauch Chunk Formation[1]	Burgoon Sandstone[1]	Huntley Mountain Formation[1]	Catskill Formation[1]	Lock Haven Formation[1]	Brallier and Harrell Formations[1]	Hamilton Group[1]
1	Lycoming Creek near Dogtown	0.8	--	5.2	18.6	34.3	41.1	--	--
2	Mill Creek upstream of Roaring Branch	0.9	--	4.8	10.3	30.1	53.9	--	--
3	Roaring Branch upstream of Brion Creek near South Union	0.1	--	2.6	13.9	62.8	20.6	--	--
4	Brion Creek near South Union	0.0	--	0.4	6.6	42.4	50.7	--	--
5	Salt Spring Run near South Union	0.0	--	0.1	8.7	35.0	56.2	--	--
6	Roaring Branch near Roaring Branch	0.0	--	1.2	10.7	42.9	45.2	--	--
7	Red Run at Ralston	77.5	2.2	16.8	3.3	0.2	--	--	--
8	Dutchman Run near Ralston	90.1	--	4.7	5.2	--	--	--	--
9	Lycoming Creek at Ralston	11.4	0.2	5.2	13.4	32.4	37.4	--	--
10	Rock Run at McIntyre Township	9.7	--	42.4	48.0	--	--	--	--
11	Hounds Run at McIntyre Township	83.1	--	14.8	2.0	--	--	--	--
12	Rock Run upstream of Lycoming Creek near Ralston	23.6	--	38.4	37.9	0.1	--	--	--
13	Frozen Run near Ralston	5.6	0.7	6.1	87.6	0.1	--	--	--
14	North Pleasant Stream at Masten	0.0	--	20.4	79.6	--	--	--	--
15	Pleasant Stream at Marsh Hill	0.4	--	34.5	58.8	6.3	--	--	--
16	Slacks Run at Bodines	0.0	--	10.2	43.8	46.1	--	--	--
17	Grays Run near Fields Station	7.2	1.4	25.2	38.3	27.8	--	--	--
18	Hagerman Run near Trout Run	0.0	--	9.6	45.6	44.8	--	--	--
19	Trout Run at Route 15 at Lewis Township	0.0	--	1.9	31.2	66.9	--	--	--
20	Trout Run upstream of Lycoming Creek at Trout Run	0.0	1.8	6.8	27.7	63.7	--	--	--

Table 2. Bedrock geologic units upstream of each sampling station in the Lycoming Creek watershed, north-central Pennsylvania.—Contuined

[USGS, U.S. Geological Survey; St., street]

Map identifier	USGS station name	Percent of basin area (shaded where value exceeds 25 percent)							
		Allegheny and Pottsville Formations[1]	Mauch Chunk Formation[1]	Burgoon Sandstone[1]	Huntley Mountain Formation[1]	Catskill Formation[1]	Lock Haven Formation[1]	Brallier and Harrell Formations[1]	Hamilton Group[1]
21	Wolf Run near Trout Run	0.1	16.4	37.2	37.7	8.6	--	--	--
22	Wolf Run upstream of Lycoming Creek near Trout Run	0.1	16.4	37.2	37.7	8.6	--	--	--
23	Daugherty Run near Powys	9.8	23.9	37.2	21.2	7.8	--	--	--
24	Lycoming Creek at Haleeka	9.7	1.3	17.4	30.1	28.6	12.8	--	--
25	Hoagland Run near Quiggleville	9.5	26.4	37.8	19.9	6.4	--	--	--
26	Stoney Gap Run near Quiggleville	12.4	18.9	9.3	10.6	37.1	11.6	--	--
27	Mill Creek near Hepburnville	0.0	--	8.7	13.0	58.4	19.9	--	--
28	Beautys Run near Hepburnville	0.0	--	--	--	79.3	20.7	--	--
29	Lycoming Creek near Heshbon	8.5	2.7	16.2	26.0	31.4	15.1	--	--
30	Bottle Run near Williamsport	0.0	--	--	--	--	97.0	3.0	
31	Lycoming Creek at 3rd St. bridge at Williamsport	8.2	2.6	15.7	25.2	30.4	16.7	1.0	0.2

[1]Description of bedrock geologic units, from Pennsylvania Department of Conservation and Natural Resources (2016).

Allegheny and Pottsville Formations — the two undifferentiated formations consist of sandstone, shale, the lower Pottsville Formation conglomerate, and some coal.

Mauch Chunk Formation — grayish-red shale and siltstone, brown, gray, and white sandstone, and some conglomerate.

Burgoon Sandstone — crossbedded, quartzitic sandstone with some conglomerate near its base. It contains minor siltstone, shale, and some very thin coaly horizons.

Huntley Mountain Formation — sandstone with some shale, siltstone, and mudstone interbeds.

Catskill Formation — succession of grayish-red sandstone, siltstone, shale, and some conglomerate and mudstone, generally in fining-upward cycles.

Lock Haven Formation — interbedded sandstone, siltstone, and very thick bedded silty shale and mudstone.

Brallier and Harrell Formations — interbedded light-gray, graded, siliceous siltstone beds and light-gray, hard, silty shales.

Hamilton Group — The Mahantango Formation and the underlying Marcellus Shale make up the Hamilton Group; composed of gray shale, siltstone, black carbonaceous shale, and limestone.

Creek. The stratified sand-and-gravel deposits along Lycoming Creek form by far the most productive aquifer in the watershed, capable of yielding as much as 3,000 gallons per minute (gal/min) of water to wells (Lloyd and Carswell, 1981). The Lycoming Creek well field is located within the glacial deposits along Lycoming Creek.

Land Cover and Use

Lycoming Creek watershed is primarily a mix of forested and agricultural lands with some small areas of past coal mining and more recent suburban and commercial development. About 79 percent of the land is characterized as forested and 15 percent agricultural in the 2011 National Land Cover Database (NLCD) (Homer and others, 2015). The land cover classes are illustrated in figure 4 and table 3. The land cover is related to the physiography and geology of the watershed and land ownership. Agricultural lands are concentrated in the northern and southern parts of the watershed and along Lycoming Creek. These areas are underlain predominantly by siltstone and shale beds of Devonian age, and are privately owned. Most of the forested lands are in the rugged topography in the middle part of the watershed within the Deep Valleys and Glaciated High Plateau sections of the Appalachian Plateaus Physiographic Province, which is underlain by the coarser clastic bedrock of Mississippian and Pennsylvanian age. Large tracts of the forest are on public lands managed as Pennsylvania State Forest or Game Lands.

The Lycoming Creek watershed is not densely populated. The creek joins the West Branch Susquehanna River within the city of Williamsport, but only about 4 percent of the watershed is categorized as developed in the NLCD dataset. The population of Williamsport in 2010 was 29,381 (U.S. Census Bureau, 2010). The developed area is concentrated in the southern part of the watershed within and near the city of Williamsport, and in the valley along the main stem of Lycoming Creek. U.S. Route 15 is a major north-south transportation artery. From Williamsport, it follows Lycoming Creek north for about 12.5 miles, turns northwest up the Trout Run valley, and leaves the basin at the headwaters of the Trout Run watershed.

Treated wastewater from the city of Williamsport is discharged to the West Branch Susquehanna River downstream from the confluence with Lycoming Creek. Four discharges of septic or treated sewage waste to Lycoming Creek are reported from manufacturing facilities (Pennsylvania Department of Environmental Protection, 2017). They are downstream from the mouth of Grays Run (site 17 on fig. 1).

Coal has been mined in the Lycoming Creek watershed by surface and underground methods. The coal occurs in the Allegheny Formation, and to a lesser degree, in the Pottsville Formation, which is part of Pennsylvania's north-central bituminous coal field (fig. 5). Some of the areas categorized on figure 4 as barren land are old mining sites. Five of the tributary watersheds (Red Run, Dutchman Run, Rock Run, Frozen Run, and Hoagland Run) contain areas that were formerly mined (table 3).

Although small deposits of oil and gas have been found in the past (Pennsylvania Department of Conservation and Natural Resources, 2016), few wells were drilled in the Lycoming Creek watershed until the beginning of exploration for natural gas from the Marcellus Shale. Six conventional vertical gas wells, all drilled prior to 2007 and subsequently plugged, are in the watershed (Pennsylvania Department of Environmental Protection, 2016a). Between July 23, 2007, and August 1, 2011, thirty-eight well pads were constructed and 65 wells were drilled to produce natural gas from the Marcellus Shale (Pennsylvania Department of Environmental Protection, 2016a). In 2011, drilling was concentrated in the northern and western parts of the watershed (fig. 5); by the end of 2015, 213 additional wells had been drilled.

Hydrologic Setting

There are about 530 miles of mapped streams within the Lycoming Creek watershed (U.S. Geological Survey, 2016a). The three largest tributaries to Lycoming Creek (in terms of watershed area) are Roaring Branch, Pleasant Stream, and Rock Run (fig. 1). Streamflow in Lycoming Creek and its tributaries originates from precipitation within the watershed. Normal average-annual precipitation for the watershed was 39.4 inches during 1971–2000, but it varies between 33 and 43 inches depending on location (Prism Climate Group, 2003). Runoff measured in Lycoming Creek near Trout Run at USGS streamgage 01550000 during the same period, expressed as a depth over the watershed, was 24.9 inches (63 percent of precipitation).

Precipitation that is not lost to evapotranspiration either runs off directly to streams or infiltrates the soil and glacial overburden and moves downward to the water table through fractures in bedrock or through open pores in the sand-and-gravel aquifer. Groundwater moves from areas of high hydraulic head beneath hills toward areas of lower hydraulic head in valleys, where it discharges to streams and springs. Some groundwater probably moves beneath small headwater streams to discharge in larger streams at lower altitudes. The groundwater-flow system probably consists of shallow flow paths of recently recharged water that discharge to headwater streams, nested within deeper flow paths of older groundwater that discharge to the main stem of Lycoming Creek and its major tributaries.

The depth of groundwater circulation is not accurately known, but according to Lloyd and Carswell (1981), most groundwater discharging as base flow to streams probably has circulated less than about 150 feet below land surface. The quality of base flow in streams is affected by the residence time of water in the aquifer; old groundwater that has followed a long flow path tends to have higher concentrations of dissolved solids than recently recharge groundwater (Back and others, 1993, p. 117). On the basis of hydrograph separation

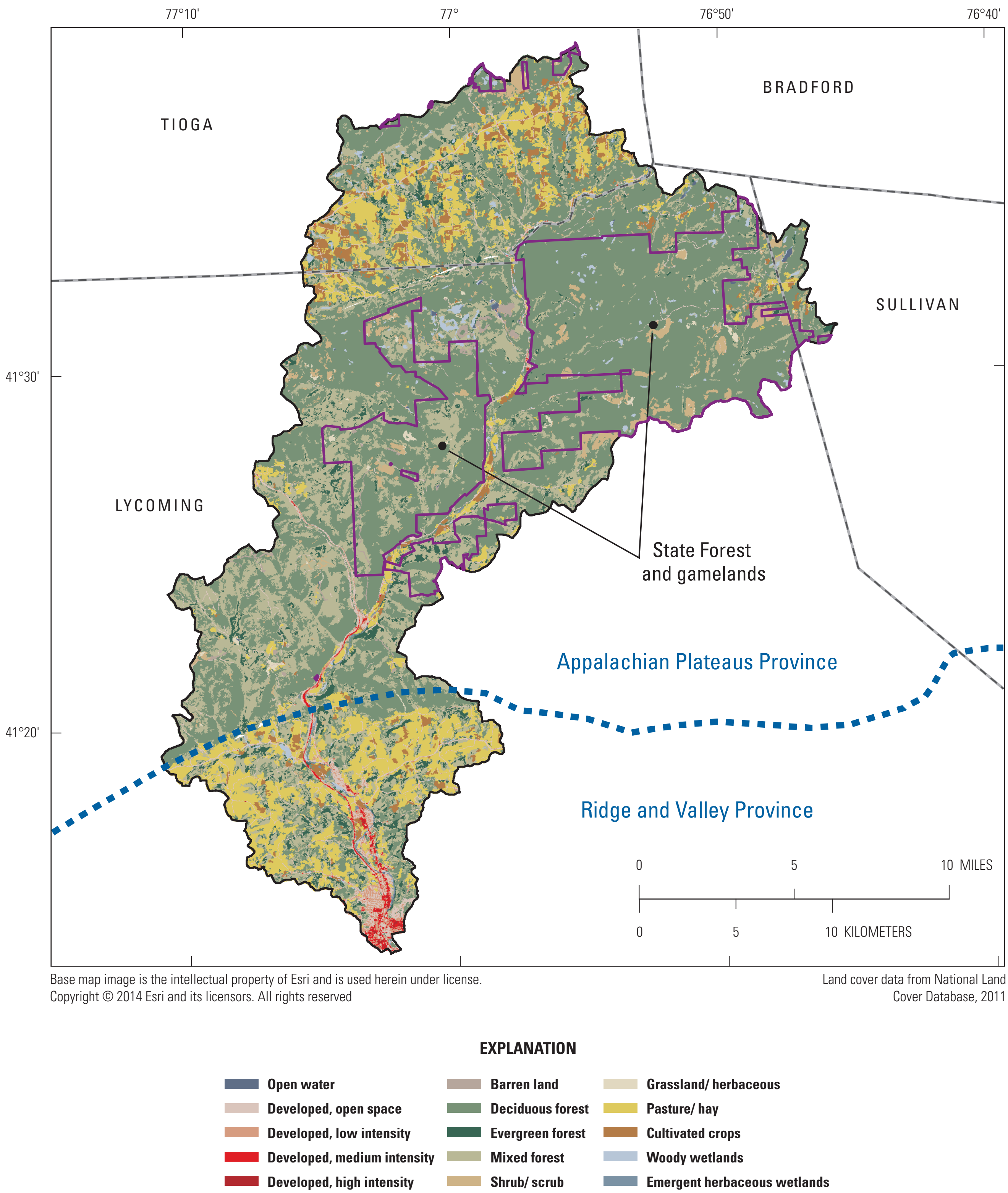


Figure 4. Land cover as shown in the 2011 National Land Cover Database within the Lycoming Creek watershed in north-central Pennsylvania.

Table 3. Land cover and use upstream of each sampling location in the Lycoming Creek watershed, north-central Pennsylvania.

[USGS, U.S. Geological Survey; St., street; --, land use category not present; shading indicates basin having greater than 10 percent of land use in that category]

Map identifier	USGS station name	Percent of basin area (shaded where value exceeds 10 percent)						Marcellus gas wells drilled (number and density per square mile)[1]	Historical coal mining in water-shed?
		Water	Developed	Barren	Forest	Pasture and crops	Wetland		
1	Lycoming Creek near Dogtown	0.07	3.36	--	66.17	28.79	1.61	12/0.77	
2	Mill Creek upstream of Roaring Branch	0.05	3.48	--	68.34	26.53	1.59	--	
3	Roaring Branch upstream of Brion Creek near South Union	--	4.20	--	55.70	39.83	0.27	--	
4	Brion Creek near South Union	0.21	2.63	0.03	59.17	35.92	2.08	2/0.72	
5	Salt Spring Run near South Union	0.03	3.86	--	78.86	14.71	1.23	3/0.60	
6	Roaring Branch near Roaring Branch	0.09	3.16	0.01	62.87	32.06	1.82	1/0.13	
7	Red Run at Ralston	1.55	6.63	4.94	83.33	1.05	7.44	7/1.22	Yes
8	Dutchman Run near Ralston	--	1.63	--	98.37	--	--	--	Yes
9	Lycoming Creek at Ralston	0.19	3.80	0.64	69.42	24.52	2.07	--	
10	Rock Run at McIntyre Township	0.54	2.05	0.16	91.43	3.95	2.03	3/0.52	
11	Hounds Run at McIntyre Town-ship	--	--	--	98.82	0.10	1.08	--	
12	Rock Run upstream of Lycoming Creek near Ralston	0.35	1.55	0.13	93.42	2.59	2.08	--	Yes
13	Frozen Run near Ralston	--	2.12	1.38	94.13	0.45	3.30	--	Yes
14	North Pleasant Stream at Masten	--	2.04	--	83.65	14.08	0.23	--	
15	Pleasant Stream at Marsh Hill	--	0.62	0.02	95.77	2.88	0.72	--	
16	Slacks Run at Bodines	--	1.92	0.50	95.02	3.06	--	3/0.40	

Table 3. Land cover and use upstream of each sampling location in the Lycoming Creek watershed, north-central Pennsylvania.—Continued

[USGS, U.S. Geological Survey; St., street; --, land use category not present; shading indicates basin having greater than 10 percent of land use in that category]

Map identifier	USGS station name	Percent of basin area (shaded where value exceeds 10 percent)						Marcellus gas wells drilled (number and density per square mile)[1]	Historical coal mining in watershed?
		Water	Developed	Barren	Forest	Pasture and crops	Wetland		
17	Grays Run near Fields Station	0.04	0.87	0.24	97.70	0.99	0.41	3/0.17	
18	Hagerman Run near Trout Run	--	1.93	1.66	97.82	0.25	--	--	
19	Trout Run at Route 15 at Lewis Township	--	1.04	0.95	97.31	1.64	--	4/0.54	
20	Trout Run upstream of Lycoming Creek at Trout Run	--	4.62	0.70	91.00	4.38	--	1/0.12	
21	Wolf Run near Trout Run	0.08	2.43	1.42	97.00	0.49	--	3/0.15	
22	Wolf Run upstream of Lycoming Creek near Trout Run	0.08	2.21	1.38	97.22	0.49	--	--	
23	Daugherty Run near Powys	--	1.92	0.52	95.53	2.55	--	1/0.07	
24	Lycoming Creek at Haleeka	0.12	2.89	0.46	84.87	10.77	1.35	--	
25	Hoagland Run near Quiggleville	0.05	3.52	1.56	93.21	3.13	0.08	10/0.94	Yes
26	Stoney Gap Run near Quigg-leville	--	4.00	0.01	69.86	25.98	0.17	6/0.82	Yes
27	Mill Creek near Hepburnville	0.02	5.01	0.24	48.98	45.78	0.21	5/0.45	
28	Beautys Run near Hepburnville	--	4.45	--	45.69	49.86	--	--	
29	Lycoming Creek near Heshbon	0.11	3.69	0.45	80.14	14.82	1.23	--	
30	Bottle Run near Williamsport	0.05	11.41	--	50.13	37.56	0.85	--	
31	Lycoming Creek at 3rd St. bridge at Williamsport	0.12	4.60	0.43	78.97	15.07	1.23	--	

[1]Not computed for four sites on the main stem of Lycoming Creek below Dogtown.

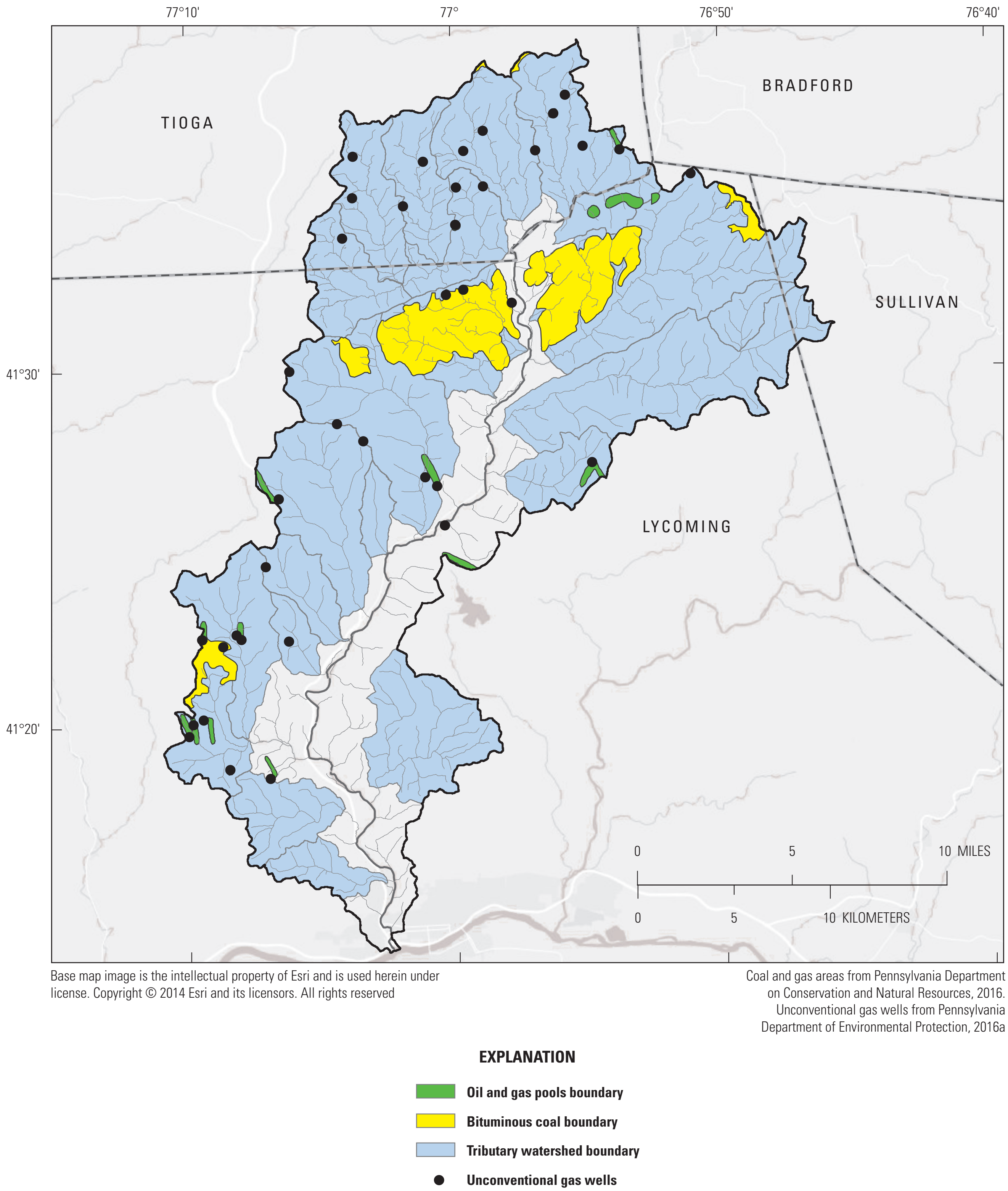


Figure 5. Underlying bituminous coalbeds and oil and gas pools in the Lycoming Creek watershed in north-central Pennsylvania. Unconventional gas wells were drilled before August 1, 2011.

(Risser and others, 2005), groundwater discharge to Lycoming Creek near Trout Run provided about two-thirds of the total flow in the stream during 1930–2001.

Methods

Surface water was sampled by the USGS and PaDEP during August 1–3, 2011 at 31 locations in Lycoming Creek watershed. The process of selecting the sampling sites, collecting and analyzing the water samples, and assessing the quality of the data is described in this section.

Site Selection

Surface-water sites were selected in coordination with WMWA and PaDEP. Eleven sites in the watershed were already established and were being sampled in 2011 by PaDEP for a regulatory program. Those sites and others locations were visited in the field with WMWA and 31 sites in total were selected for sampling (fig. 1 and table 1). Five sampling sites were on the main stem of Lycoming Creek. The watershed areas for the main-stem sites ranged from 15.6 mi^2 for the most upstream site near Dogtown to 272 mi^2 for the most downstream site at the 3rd Street Bridge near the mouth of Lycoming Creek. The other 26 sampling sites were located on 22 tributary streams. Four of the tributaries—Roaring Branch, Rock Run, Trout Run, and Wolf Run—were each sampled at two sites. Watersheds areas ranged from 1.1 to 30.5 mi^2 for the tributary streams that were sampled.

Sampling sites on tributary streams were selected to represent watersheds with various land uses (forest, agriculture, resource extraction, urban development) and underlying geology (tables 2 and 3). Samples from these streams provide a preliminary survey of base-flow water quality for those settings. Streams were sampled throughout the watershed to identify the chemical signatures of water in tributaries draining differing land uses and geology.

Sample Collection

The surface-water samples were collected during a relatively dry period August 1–3, 2011, during base-flow conditions. At the beginning of sample collection on August 1, 2011, streamflow in Lycoming Creek near Trout Run (USGS streamgage 01550000) was 21 cubic feet per second (ft3/s) (fig. 6). Lower flows were recorded at that streamgage only about 10 percent of the time during 100 years of record; although some soil interflow may be contributing, at this low-flow condition samples represent predominantly groundwater discharge to streams. A low, base-flow condition was targeted for sampling because the WMWA wells are only used during dry months to supplement the surface-water from sources located south of the West Branch Susquehanna River; thus, the reconnaissance sampling was timed to occur during the typical conditions when the well field would be in operation and have the potential to capture infiltration from Lycoming Creek.

All environmental and quality-assurance samples were collected by three crews during a 48-hour period between August 1, 2011, at 10:30 a.m. and August 3, 2011, at 10:30 a.m. Although not expected, scattered storms moved across northern Pennsylvania during the sampling period. Neither precipitation nor turbid stream water were reported by the crews during sample collection at any of the sites, but the USGS streamgage on Lycoming Creek near Trout Run did show that the flow in Lycoming Creek changed during the hours when samples were collected (fig. 7). At the time when the first sample was collected (August 1 at 10:30 a.m.) flow was 21 ft^3/s; the flow peaked at 29 ft^3/s between August 2 at 8:45PM and August 3 at 8:00AM, and then fell to 27 ft^3/s when the last sample was collected on August 3 at 10:30 a.m.

The extent to which changes in streamflow could have affected the chemical quality of the water is not known, but it is probably small. The increase in flow from 21 to 29 ft^3/s is not a storm peak; it still represents low flow in Lycoming Creek that has historically been lower only about 11 percent of the time. Also, based on multiple samples collected during different flow conditions in Lycoming Creek near Trout Run, a change in streamflow from the measured flow of 21 to 29 ft^3/s would be expected to only decrease specific conductance from about 83 to 80 µS/cm at 25 degrees Celsius (fig. 8).

Surface-water samples were collected by both USGS and PaDEP personnel. Although the sample-collection was coordinated, sampling protocols used by the agencies differed. USGS personnel collected environmental samples at 20 sites (table 1) and processed them using standard field methods of the U.S. Geological Survey (U.S. Geological Survey, variously dated). Each sample was collected using the equal-width increment (EWI) method, in which aliquots of water are collected across the stream with vertical transects at each increment and mixed in a polyethylene churn. Sample bottles were filled by drawing the composite water from the churn with a peristaltic pump and filtering through a 0.45-micron capsule filter. Samples were preserved with acid and chilled (if necessary), and shipped overnight to the appropriate laboratory under chain-of-custody protocols.

PaDEP personnel collected environmental surface-water samples at the 11 sites that they had previously established (table 1) by wading to near the centroid of flow in the stream and filling sample bottles by dipping them below the water surface at a single depth. Samples were not acidified or filtered in the field. They were chilled (if necessary), and delivered to the PaDEP laboratory by courier under chain-of-custody protocols.

Quality-assurance samples were collected at five sites (table 1) by both USGS and PaDEP personnel to evaluate the effects of different sample-collection protocols and laboratories used to analyze the water chemistry. Replicate samples were taken by USGS and PaDEP personnel using the EWI and single-point methods, respectively, and these samples were sent to both the USGS and PaDEP laboratories to compare results.

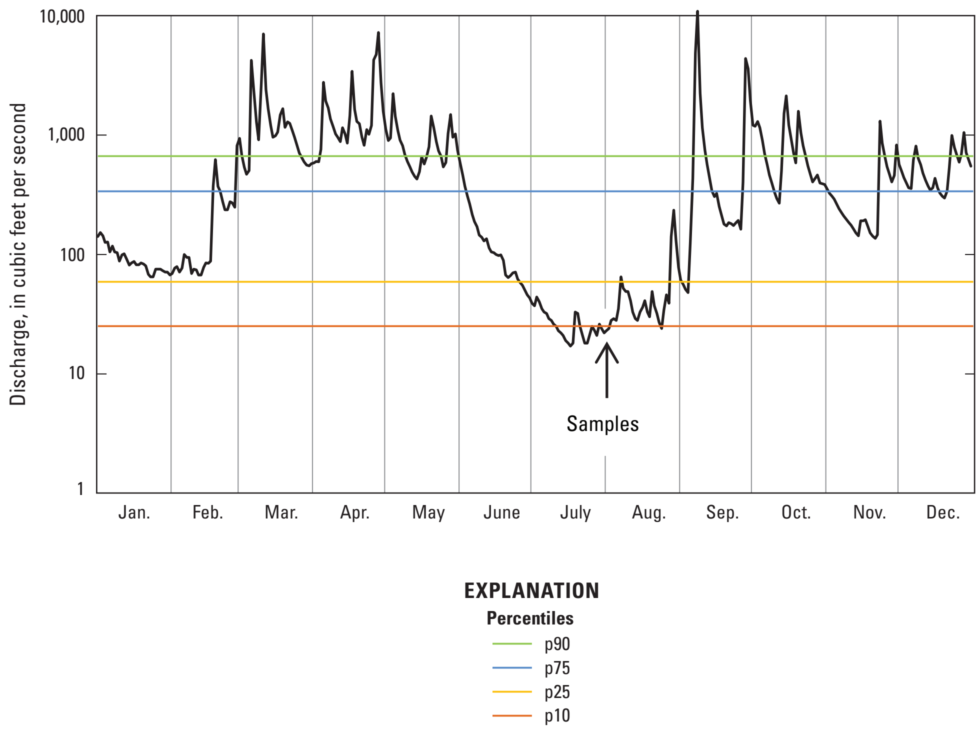


Figure 6. Hydrograph of Lycoming Creek near Trout Run at USGS streamgage 01550000, showing streamflow conditions when water samples were taken in relation to streamflow during 2011 and to streamflow recorded at the streamgage from 1913 to 2014.

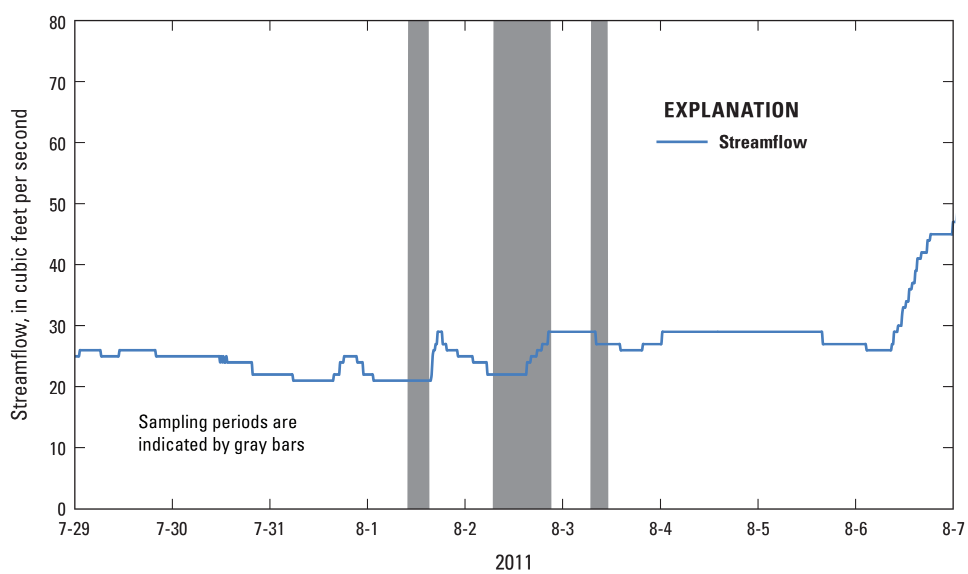


Figure 7. Streamflow in Lycoming Creek near Trout Run recorded at USGS streamgage 01550000, and periods when stream samples were collected in the Lycoming Creek watershed, August 1–3, 2011.

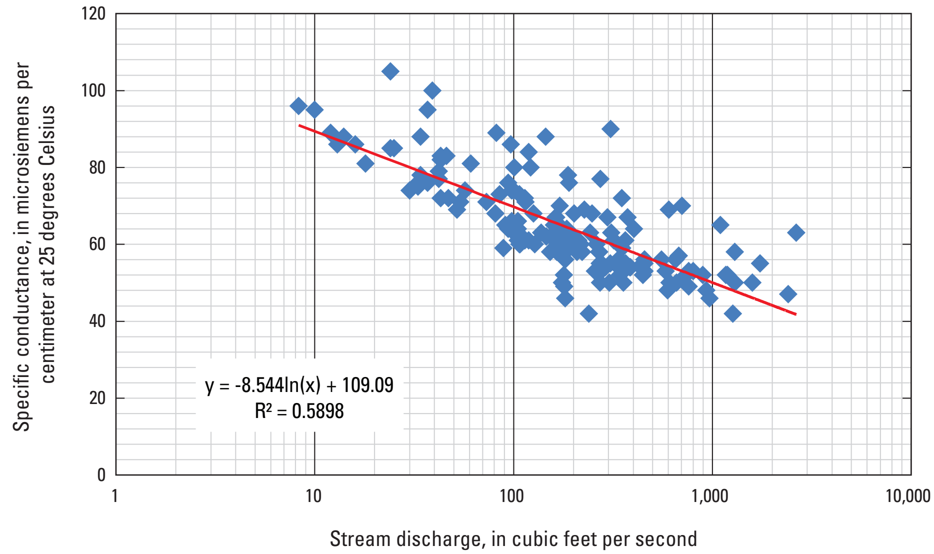


Figure 8. Stream discharge and specific conductance of 160 samples collected at Lycoming Creek near Trout Run for the Pennsylvania Water-Quality Network during 1975–2015.

Sample Analysis

Water samples collected by USGS were analyzed for field parameters, major ions, nutrients, trace metals, and radiochemicals. The pH, water temperature, specific conductance, and dissolved oxygen were measured in the stream with a multiparameter meter. Turbidity was measured in the field with a portable turbidity meter. Acid neutralizing capacity was titrated either in the field at the time of sample collection or at the end of the day. USGS personnel measured stream discharge at each location at the time of sample collection. For analysis of major ions, nutrients, and trace metals, water samples were sent to the USGS National Water Quality Laboratory (NWQL) in Denver, Colo. Samples for radiochemicals were sent Eberline Services Inc., a private laboratory under contract to the NWQL. The NWQL is certified by the National Environmental Laboratory Accreditation Program (NELAP) for analysis of nonpotable waters by USGS methods. Details about the NWQL accreditations, laboratory audits, and proficiency testing are available online at http://nwql.usgs.gov/quality.shtml. The Eberline Services, Inc., laboratory is also certified by the EPA.

Water samples collected by PaDEP were analyzed for major ions, nutrients, and trace metals. Samples were sent to the PaDEP laboratory in Harrisburg, Pa. The PaDEP laboratory is certified by NELAP for analytical testing of drinking water and nonpotable water and it participates in the USGS Standard Reference Sample Project (U.S. Geological Survey, 2016b).

Reporting Limits

The reporting limits for the analytical methods requested from the USGS NWQL and PaDEP laboratory differed for all of the water-quality constituents analyzed in this study (table 4). For the nutrients, the reporting limits were similar. Reporting limits differed substantially for trace metals and some major constituents. In some cases, the differences were greater than one order of magnitude. For example, the USGS NQWL reporting limit for sulfate was 0.09 milligrams per liter (mg/L), and the PaDEP laboratory reporting limit was 15 mg/L. As a result, for some water-quality constituents, there are instances where most or all of the 20 sites sampled by USGS have values greater than the reporting level, but all 11 sites sampled by PaDEP are censored as less than the reporting level. The discussion of results for many of the trace metals is limited to the 20 USGS sample sites because of these differences.

Table 4. Comparison of water-quality constituents analyzed by the Pennsylvania Department of Environmental Protection and U.S. Geological Survey laboratories and reporting limits for samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.

[Shading indicates constituents analyzed by both laboratories. USGS, U.S. Geological Survey; PaDEP, Pennsylvania Department of Environmental Protection; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; NA; not analyzed]

Constituent	Unit	Reporting limit	
		USGS	PaDEP
Major constituents			
Dissolved solids dried at 180 degrees Celsius	mg/L	12	2
Calcium	mg/L	0.022	0.03
Magnesium	mg/L	0.008	0.01
Potassium	mg/L	0.022	1
Sodium	mg/L	0.06	0.2
Alkalinity, as calcium carbonate	mg/L	4	0
Bromide	mg/L	0.01	0.2
Chloride	mg/L	0.06	0.5
Sulfate	mg/L	0.09	15
Fluoride	mg/L	0.04	NA
Silica, as SiO_2	mg/L	0.029	NA
Nutrients			
Ammonia, as nitrogen	mg/L	0.01	0.02
Nitrate, as nitrogen	mg/L	0.02	0.04
Nitrite, as nitrogen	mg/L	0.001	0.01
Phosphorus, as phosphorus	mg/L	0.02	0.01
Ammonia plus organic nitrogen, as nitrogen	mg/L	0.05	NA
Nitrate plus nitrite, as nitrogen	mg/L	0.02	NA
Organic nitrogen, as nitrogen	mg/L	0.07	NA
Total nitrogen, as nitrogen	mg/L	0.05	NA
Ortho phosphate, as phosphorus	mg/L	0.004	NA
Trace constituents			
Aluminum	mg/L	1.7	10 or 200
Arsenic	mg/L	0.022[a]	3
Barium	mg/L	0.07	0.01
Boron	mg/L	3	200
Cadmium	mg/L	0.016	0.2
Chromium	mg/L	0.06	50
Copper	mg/L	0.5	4
Iron	mg/L	3.2	20
Lead	mg/L	0.015	1
Manganese	mg/L	0.13[a]	10
Nickel	mg/L	0.09	4
Selenium	mg/L	0.03	7
Strontium	mg/L	0.2	0.01
Zinc	mg/L	1.4	5
Antimony	mg/L	0.027	NA
Beryllium	mg/L	0.006	NA
Cobalt	mg/L	0.02[a]	NA

Table 4. Comparison of water-quality constituents analyzed by the Pennsylvania Department of Environmental Protection and U.S. Geological Survey laboratories and reporting limits for samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Shading indicates constituents analyzed by both laboratories. USGS, U.S. Geological Survey; PaDEP, Pennsylvania Department of Environmental Protection; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; NA; not analyzed]

Constituent	Unit	Reporting limit	
		USGS	PaDEP
Lithium	mg/L	0.22	NA
Molybdenum	mg/L	0.014	NA
Silver	mg/L	0.005	NA
Uranium (natural)	mg/L	0.004	NA
Radiochemicals			
Alpha radioactivity, 30-day count	pCi/L	3	NA
Alpha radioactivity, 72-hour count	pCi/L	3	NA
Beta radioactivity, 30-day count	pCi/L	4	NA
Beta radioactivity, 72-hour count	pCi/L	4	NA

[a]Reporting limits for the project were raised to five times the concentration found in the blank sample for cobalt (0.39 mg/L), manganese (0.85 mg/L), and arsenic (0.15 mg/L).

Quality Assurance

Quality-assurance samples were collected to evaluate possible contamination, accuracy of laboratory results, reproducibility of results, and possible bias caused by the different sampling protocols and laboratories used by USGS and PaDEP. This was done by the analysis of blanks, standard-reference samples, replicate samples, and duplicate samples collected at the same site by different methods. Analytical results for quality assurance samples are presented in tables; results are also available online in the USGS NWIS (U.S. Geological Survey, 2017).

Blank and Standard Reference Samples

Reagent-grade inorganic-free blank water was poured into a polyethylene churn and processed in the field at the Bottle Run site using standard USGS surface-water quality sampling procedures. The blank sample was analyzed by NWQL for major ions, trace metals, and nutrients. The laboratory results showed that concentrations were below reporting levels for all constituents except for cobalt, manganese, and arsenic. Those constituents were present in the blank water at 0.078, 0.17, and 0.03 micrograms per liter (µg/L), respectively (table 5). The detections indicate that concentrations reported by the NWQL at those low levels in the environmental surface-water samples might be affected by contamination introduced during the sampling or analytical process. For this study the reporting limits for cobalt, manganese, and arsenic found in the environmental samples were increased to five times the concentration found in the blank for those constituents, following guidelines cited in Mueller and others (2015, p. 19). The reported concentrations for cobalt in 13 samples, manganese in 3 samples, and arsenic in 4 samples were below the five-times threshold, so they were treated as nondetections.

One standard-reference water sample was processed in the field at the site on Slacks Run (site 16) by transferring standard-reference water into sample bottles used for the environmental samples. The standard-reference water was obtained from the NWQL Bureau of Quality Systems. It had been analyzed by many different laboratories and given a certified most-probable value and range of uncertainty for each constituent. The standard-reference sample was sent to the NWQL to evaluate accuracy for analyzing major cations, nutrients, and trace metals. Results for all constituents were acceptable with the exception of silica, nitrate plus nitrite, iron, lithium, and boron, which were noted by the NWQL Bureau of Quality Systems as being outside of two f-pseudosigmas (a statistically robust approximation of the standard deviation) from the most probable values for those constituents (table 6). These results indicate a possible high bias of values from NWQL for silica, nitrate plus nitrite, and lithium; and low bias for iron and boron. The possible bias was noted as a project data-quality indicator on the table of analytical results.

Replicate Samples

Replicate samples were obtained as aliquots of the same water composited in the sample churn at a site. Replicates were collected at Dutchman Run (site 8) and Hounds Run (site 11) to evaluate the reproducibility of results for samples collected by USGS personnel and sent to NWQL for analysis of major ions, nutrients, and trace metals (table 7). Results were reproduced within acceptable limits (differences less than 25 percent) for all constituents in the sample from Dutchman

Table 5. Concentrations reported by the U.S. Geological Survey National Water Quality Laboratory for the inorganic blank water sample (field equipment black).

[Value in parentheses is the parameter code, a unique 5-digit number used by the U.S. Geological Survey to identify a constituent; <, less than. Dark shading highlights constituents that were detected in the blank]

Constitutent	Result
Dissolved solids dried at 180 degrees Celsius, water, filtered, milligrams per liter (70300)	<12
Calcium, water, filtered, milligrams per liter (00915)	<0.022
Magnesium, water, filtered, milligrams per liter (00925)	<0.008
Potassium, water, filtered, milligrams per liter (00935)	<0.02
Sodium, water, filtered, milligrams per liter (00930)	<0.06
Bromide, water, filtered, milligrams per liter (71870)	<0.010
Chloride, water, filtered, milligrams per liter (00940)	<0.06
Fluoride, water, filtered, milligrams per liter (00950)	<0.04
Silica, water, filtered, milligrams per liter as SiO_2 (00955)	<0.029
Sulfate, water, filtered, milligrams per liter (00945)	<0.09
Ammonia plus organic nitrogen, water, unfiltered, milligrams per liter as nitrogen (00625)	<0.05
Ammonia, water, filtered, milligrams per liter as nitrogen (00608)	<0.01
Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen (00631)	<0.02
Nitrite, water, filtered, milligrams per liter as nitrogen (00613)	<0.001
Orthophosphate, water, filtered, milligrams per liter as phosphorus (00671)	<0.004
Phosphorus, water, filtered, milligrams per liter as phosphorus (00666)	<0.02
Phosphorus, water, unfiltered, milligrams per liter as phosphorus (00665)	<0.02
Aluminum, water, filtered, micrograms per liter (01106)	<1.7
Barium, water, filtered, micrograms per liter (01005)	<0.07
Beryllium, water, filtered, micrograms per liter (01010)	<0.006
Cadmium, water, filtered, micrograms per liter (01025)	<0.016
Chromium, water, filtered, micrograms per liter (01030)	<0.06
Cobalt, water, filtered, micrograms per liter (01035)	0.078
Copper, water, filtered, micrograms per liter (01040)	<0.50
Iron, water, filtered, micrograms per liter (01046)	<3.2
Lead, water, filtered, micrograms per liter (01049)	<0.015
Lithium, water, filtered, micrograms per liter (01130)	<0.05
Manganese, water, filtered, micrograms per liter (01056)	0.17
Molybdenum, water, filtered, micrograms per liter (01060)	<0.014
Nickel, water, filtered, micrograms per liter (01065)	<0.09
Silver, water, filtered, micrograms per liter (01075)	<0.005
Strontium, water, filtered, micrograms per liter (01080)	<0.20
Zinc, water, filtered, micrograms per liter (01090)	<1.4
Antimony, water, filtered, micrograms per liter (01095)	<0.027
Arsenic, water, filtered, micrograms per liter (01000)	0.03
Boron, water, filtered, micrograms per liter (01020)	<3
Selenium, water, filtered, micrograms per liter (01145)	<0.03
Uranium (natural), water, filtered, micrograms per liter (22703)	<0.004

Table 6. Comparison of concentrations reported by the U.S. Geological Survey National Water Quality Laboratory to expected values for the standard reference samples T-181 (trace metals) and N-109 (nutrients).

[Value in parentheses is the parameter code, a unique 5-digit number used by the U.S. Geological Survey to identify a constituent; Most probable value is the median value for an analyte determimed by multiple laboratories participating in the blind sample quality assurace program; NWQL, U.S. Geological Survey National Water Quality Laboratory; Percent difference = 100*((NWQL result - Most probable value)/Most probable value). Dark shading indicates the result is outside of the acceptable deviation from the most probable value. Acceptable deviation is two f-pseudosigmas (a statistically robust approximation of the standard deviation) from the most probable value]

Constitutent	Most probable value	NWQL result	Percent difference
Calcium, water, filtered, milligrams per liter (00915)	13.4	13.6	1.5
Magnesium, water, filtered, milligrams per liter (00925)	3.05	3.26	6.9
Potassium, water, filtered, milligrams per liter (00935)	1.52	1.51	-0.7
Sodium, water, filtered, milligrams per liter (00930)	15	15.2	1.3
Silica, water, filtered, milligrams per liter as SiO_2 (00955)	13.1	14.2	8.4
Ammonia, water, filtered, milligrams per liter as nitrogen (00608)	0.195	0.19	-2.6
Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen (00631)	0.191	0.21	9.9
Orthophosphate, water, filtered, milligrams per liter as phosphorus (00671)	0.193	0.2	3.6
Aluminum, water, filtered, micrograms per liter (01106)	16.2	16.6	2.5
Barium, water, filtered, micrograms per liter (01005)	25.5	24.2	-5.1
Beryllium, water, filtered, micrograms per liter (01010)	4.6	4.07	-12
Cadmium, water, filtered, micrograms per liter (01025)	1.6	1.68	5.0
Chromium, water, filtered, micrograms per liter (01030)	5.64	5.5	-2.5
Cobalt, water, filtered, micrograms per liter (01035)	5.5	5.38	-2.2
Copper, water, filtered, micrograms per liter (01040)	7.79	7.5	-3.7
Iron, water, filtered, micrograms per liter (01046)	119	68.9	-42
Lead, water, filtered, micrograms per liter (01049)	9.4	9.2	-2.1
Lithium, water, filtered, micrograms per liter (01130)	8.4	9.75	16.0
Manganese, water, filtered, micrograms per liter (01056)	11.6	12.2	5.2
Molybdenum, water, filtered, micrograms per liter (01060)	4.49	4.62	2.9
Nickel, water, filtered, micrograms per liter (01065)	4.72	4.8	1.7
Silver, water, filtered, micrograms per liter (01075)	4.3	4.26	-0.9
Strontium, water, filtered, micrograms per liter (01080)	81.6	84.6	3.7
Zinc, water, filtered, micrograms per liter (01090)	10.5	10.8	2.9
Antimony, water, filtered, micrograms per liter (01095)	3.43	3.26	-5.0
Arsenic, water, filtered, micrograms per liter (01000)	6.1	6.6	8.2
Boron, water, filtered, micrograms per liter (01020)	21	16	-24
Selenium, water, filtered, micrograms per liter (01145)	1.3	1.3	0.0
Uranium (natural), water, filtered, micrograms per liter (22703)	1.85	1.84	-0.5

Table 7. Concentrations reported by the U.S. Geological Survey National Water Quality Laboratory for replicate samples collected from two streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.

[mg/L, milligrams per liter; µg/L, micrograms per liter; N, nitrogen; P, phosphorus; PA, Pennsylvania; Twp, township; <, less than; --, not determined; positive percent difference indicates replicate value is larger than environmental sample. All samples were filtered in the field unless noted]

Constituent and USGS parameter code	Dutchman Run near Ralston, PA			Hounds Run at McIntyre Twp, PA		
	Environmental sample 8/2/11 20:30	Replicate sample 8/2/11 20:31	Percent difference	Environmental sample 8/2/11 19:00	Replicate sample 8/2/11 19:01	Percent difference
Dissolved solids dried at 180 degrees Celsius, mg/L (70300)	191	182	-4.8	14.0	17.0	19.4
Calcium, mg/L (00915)	9.34	9.37	0.3	2.12	2.15	1.4
Magnesium, mg/L (00925)	9.79	9.78	-0.1	0.637	0.635	-0.3
Potassium, mg/L (00935)	1.07	1.09	1.9	0.32	0.35	9.0
Sodium, mg/L (00930)	1.01	1.02	1.0	0.58	0.59	1.7
Bromide, mg/L (71870)	<0.01	<0.01	--	0.015	0.015	0.0
Chloride, mg/L (00940)	0.28	0.30	6.9	0.53	0.54	1.9
Fluoride, mg/L (00950)	0.09	0.08	-11.8	<0.04	<0.04	--
Silica, mg/L as SiO_2 (00955)	20.7	20.5	-1.0	4.42	4.39	-0.7
Sulfate, mg/L (00945)	130	131	0.8	6.51	6.87	5.4
Ammonia plus organic nitrogen, unfiltered, mg/L as N (00625)	<0.05	0.15	--	<0.05	<0.05	--
Ammonia, mg/L as N (00608)	<0.01	0.02	--	<0.01	<0.01	--
Nitrate plus nitrite, mg/L as N (00631)	0.06	0.06	0.0	0.33	0.33	0.0
Nitrite, mg/L as N (00613)	<0.001	<0.001	--	<0.001	<0.001	--
Orthophosphate, mg/L as P (00671)	0.005	0.004	-22.2	<0.004	<0.004	--
Phosphorus, mg/L as P (00666)	<0.02	<0.02	--	<0.02	<0.02	--
Phosphorus, unfiltered, mg/L as P (00665)	<0.02	<0.02	--	<0.02	<0.02	--
Aluminum, µg/L (01106)	4,950	4,810	-2.9	27.8	21.2	-26.9
Barium, µg/L (01005)	32.3	31.9	-1.2	21.9	21.9	0.0
Beryllium, µg/L (01010)	3.38	3.77	10.9	0.063	0.063	0.0
Cadmium, µg/L (01025)	0.452	0.463	2.4	0.105	0.101	3.9
Chromium, µg/L (01030)	1.0	0.99	1.0	<0.06	<0.06	--
Cobalt, µg/L (01035)	45.1	45.2	0.2	0.043	0.024	56.7
Copper, µg/L (01040)	20.5	20.4	0.5	0.68	<0.50	--
Iron, µg/L (01046)	498	495	0.6	4.7	<3.2	--
Lead, µg/L (01049)	4.06	4.09	0.7	0.028	0.016	54.5
Lithium, µg/L (01130)	49.2	47.6	3.3	0.91	0.91	0.0
Manganese, µg/L (01056)	1,770	1,780	0.6	6.13	6.9	11.8
Molybdenum, µg/L (01060)	<0.014	<0.014	--	<0.014	<0.014	--
Nickel, µg/L (01065)	90.2	90	0.2	2.1	2	4.9
Silver, µg/L (01075)	<0.005	<0.005	--	<0.005	<0.005	--
Strontium, µg/L (01080)	44.9	43.7	2.7	19.5	19.7	1.0
Zinc, µg/L (01090)	190	189	0.5	8.8	8.8	0.0
Antimony, µg/L (01095)	<0.027	<0.027	--	<0.027	<0.027	--
Arsenic, µg/L (01000)	0.20	0.23	14.0	0.08	0.07	13.3
Boron, µg/L (01020)	5	5	0.0	4	4	0.0
Selenium, µg/L (01145)	0.83	0.8	3.7	0.06	0.05	18.2
Uranium (natural), µg/L (22703)	0.688	0.68	1.2	<0.004	<0.004	--

Run. In the sample from Hounds Run, results for aluminum, cobalt, and lead all differed by more than 25 percent. This was partly the result of comparing the rounded values of very small concentrations. The water sample from Hounds Run has a very low concentration of total dissolved solids (between 14 and 17 mg/L) causing very small absolute differences in analytical results to be shown as a large percent difference.

Replicate samples were also collected by USGS EWI methods at five sites to compare results from different laboratories (table 8). The comparison of filtered samples analyzed by both labs was not very useful because so many of the results were censored. The comparison of filtered to unfiltered samples for selected cations showed results that were generally in good agreement. One analysis for barium was 51 percent greater in the unfiltered sample analyzed by PaDEP than in the filtered sample analyzed by USGS for Pleasant Stream at Marsh Hill (table 8); however, because barium results agreed closely (within 5 percent) in samples from the other four stream sites, the barium data were not qualified.

Duplicate Samples Collected by EWI and Single-Point Methods

Duplicate samples were obtained by sampling stream water at the same site using the EWI method and field protocols used by USGS, and the single-point method used by PaDEP. The duplicate samples were sent to both the NWQL and PaDEP laboratories for analysis. The analytical results from NWQL did not indicate any consistent and substantial bias of one collection method over the other (table 9*A*). Bromide was consistently greater in the single-point samples, but the absolute differences in concentration were slight. Aluminum results were the most variable, with differences as large as 63 percent between the methods; but without consistent bias. The PaDEP laboratory provided fewer results to compare because they were censored at a higher reporting level (table 9*B*). The greatest difference was 45 percent in one result for barium in Pleasant Stream at Marsh Hill, but the other duplicates for barium were in good agreement.

Table 8. Comparison of analytical results for samples analyzed by the U.S. Geological Survey Laboratory and Pennsylvania Department of Environmental Protection Laboratory.

[USGS, sample analyzed by the U.S. Geological Survey Laboratory; PaDEP, sample analyzed by the Pennsylvania Department of Environmental Quality Laboratory; % Diff, percent difference; mg/L, milligrams per liter; µg/L, micrograms per liter; PA, Pennsylvania; --, could not compare; <, less than; positive % difference indicates PaDEP result is greater than USGS result. All samples were collected by the equal-width-interval composite method]

Constituent and USGS parameter code	Roaring Branch near Roaring Branch, PA			Lycoming Creek at Ralston, PA			Grays Run near fields station, PA			Pleasant Stream at Marsh Hill, PA			Mill Creek near Hepburnville, PA		
	8/1/2011 10:30 USGS	8/1/2011 10:30 PaDEP	% Diff	8/1/2011 13:15 USGS	8/1/2011 13:15 PaDEP	% Diff	8/2/2011 11:00 USGS	8/2/2011 11:00 PaDEP	% Diff	8/2/2011 08:30 USGS	8/2/2011 08:30 PaDEP	% Diff	8/2/2011 13:00 USGS	8/2/2011 13:00 PaDEP	% Diff
Samples were filtered for both USGS and PaDEP laboratories for these analytes															
Dissolved solids dried at 180 degrees Celsius, mg/L (70300)	79	74	-6.5	85	78	-8.6	32	30	-6.5	34	40	16.2	106	126	17.2
Aluminum, µg/L (01106)	4.2	<200	--	75.7	<200	--	3.1	<200	--	2.4	<200	--	4.7	<200	--
Cadmium, µg/L (01025)	<0.016	<0.2	--	0.053	<0.2	--	<0.016	<0.2	--	<0.016	<0.2	--	<0.016	<0.2	--
Copper, µg/L (01040)	0.72	<4	--	0.88	<4	--	<0.50	<4	--	<0.50	<4	--	0.79	<4	--
Iron, µg/L (01046)	<3.2	<20	--	3.4	<20	--	5.5	<20	--	3.2	<20	--	16.4	<20	--
Lead, µg/L (01049)	<0.015	<1	--	0.024	<1	--	<0.015	<1	--	<0.015	<1	--	0.020	<1	--
Nickel, µg/L (01065)	0.22	<4	--	6.0	6.1	1.7	0.27	<4	--	0.21	<4	--	0.37	<4	--
Zinc, µg/L (01090)	<1.4	<5	--	9.9	10	1.0	1.9	7	114.6	<1.4	6	--	<1.4	7	--
Arsenic, µg/L (01000)	0.39	<3	--	0.23	<3	--	0.11	<3	--	0.12	<3	--	0.64	<3	--
USGS samples were filtered; PaDEP samples were unfiltered for these analytes															
Ammonia, mg/L as nitrogen	<0.01	<0.02	--	<0.01	<0.02	--	<0.01	<0.02	--	<0.01	<0.02	--	<0.01	<0.02	--
Calcium, mg/L	11.8	12	1.7	10.3	11	6.6	4.36	4.2	-3.7	6.06	6.0	-1.0	19.4	20	3.0
Magnesium, mg/L	2.17	2.1	-3.3	3.09	3.0	-3.0	0.93	0.9	-3.3	1.11	1.1	-0.9	4.3	4.2	-2.4
Bromide, mg/L	0.013	<0.2	--	0.017	<0.2	--	<0.010	<0.2	--	<0.010	<0.2	--	0.013	<0.2	--
Chloride, mg/L	6.32	5.5	-13.9	6.41	5.3	-19.0	0.68	1.0	38.4	1.10	1.3	16.7	20.3	19	-5.1
Sulfate, mg/L	8.37	<15.0	--	23.4	21	-10.8	6.49	<15.0	--	6.06	<15.0	--	6.54	<15.0	--
Barium, µg/L	33.6	34	1.2	38.6	40	3.6	21.2	22	3.7	16	27	51.2	40.9	43	5.0
Chromium, µg/L	<0.06	<50	--	0.09	<50	--	<0.06	<50	--	<0.06	<50	--	0.07	<50	--
Manganese, µg/L	2.37	<10	--	76.6	90	16.1	1.63	<10	--	3.14	<10	--	3.18	<10	--
Strontium, µg/L	56.7	50	-12.6	59.3	60	1.2	21.9	20	-9.1	33.1	30	-9.8	72.2	70	-3.1
Phosphorus, mg/L as phosphorus	<0.02	0.010	--	<0.02	<0.010	--	<0.02	<0.010	--	<0.02	<0.010	--	0.04	0.024	-50.0

Table 9A. Comparison of analytical results for samples collected by the equal-width-interval composite method (EWI) and single-point sample method, analyzed by the U.S. Geologcical Survey National Water Quality Laboratory.

[EWI, equal-width-interval composite sample; SP, single point dipped sample; positive % difference indicates result for SP sample is larger than EWI sample; PA, Pennsylvania; mg/L, milligrams per liter; µg/L, micrograms per liter; --, could not compare; % Diff, percent difference; <, less than; All samples were filtered in the field and analyzed by to the U.S. Geological Survey National Water Quality Laboratory]

Constituent and USGS parameter code	Roaring Branch near Roaring Branch, PA			Lycoming Creek at Ralston, PA			Grays Run near fields station, PA			Pleasant Stream at Marsh Hill, PA			Mill Creek near Hepburnville, PA		
	8/1/2011 10:30 EWI	8/1/2011 10:45 SP	% Diff	8/1/2011 13:15 EWI	8/1/2011 13:30 SP	% Diff	8/2/2011 11:00 EWI	8/2/2011 11:30 SP	% Diff	8/2/2011 08:30 EWI	8/2/2011 09:00 SP	% Diff	8/2/2011 13:00 EWI	8/2/2011 13:30 SP	% Diff
Dissolved solids dried at 180 deg C, mg/L (70300)	79	65	-19.4	85	81	-4.8	32	28	-13.3	34	36	5.7	106	102	-3.8
Calcium, mg/L (00915)	11.8	11.6	-1.7	10.3	10.1	-2.0	4.36	4.32	-0.9	6.06	6.05	-0.2	19.4	19.4	0.0
Magnesium, mg/L (00925)	2.17	2.14	-1.4	3.09	3.02	-2.3	0.93	0.926	-0.4	1.11	1.12	0.9	4.3	4.3	0.0
Bromide, mg/L (71870)	0.013	0.016	20.7	0.0165	0.020	19.2	<0.010	<0.010	--	<0.010	<0.010	--	0.013	0.017	26.7
Chloride, mg/L (00940)	6.32	6.32	0.0	6.41	6.44	0.5	0.678	0.679	0.1	1.1	1.02	-7.5	20.3	20.1	-1.0
Sulfate, mg/L (00945)	8.37	8.26	-1.3	23.4	23.5	0.4	6.49	6.62	2.0	6.06	6.15	1.5	6.54	7	6.8
Phosphorus, mg/L as phosphorus (00666)	<0.020	<0.020	--	<0.020	<0.020	--	<0.020	<0.020	--	<0.020	<0.020	--	0.04	0.04	0.0
Aluminum, µg/L (01106)	4.2	6.3	40.0	75.7	39.4	-63.1	3.1	4.4	34.7	2.4	2.8	15.4	4.7	4.1	-13.6
Barium, µg/L (01005)	33.6	32.2	-4.3	38.6	37.6	-2.6	21.2	21.2	0.0	16.0	15.7	-1.9	40.9	40.7	-0.5
Cadmium, µg/L (01025)	<0.016	<0.016	--	0.053	0.045	-16.3	<0.016	<0.016	--	<0.016	<0.016	--	<0.016	<0.016	--
Chromium, µg/L (01030)	<0.06	<0.06	--	0.09	<0.06	--	<0.06	<0.06	--	<0.06	<0.06	--	<0.06	<0.06	--
Copper, µg/L (01040)	0.72	0.72	0.0	0.88	0.69	-24.2	<0.5	<0.5	--	<0.5	<0.5	--	0.79	0.63	-22.5
Iron, µg/L (01046)	<3.2	3.5	--	3.4	<3.2	--	5.5	5.9	7.0	3.2	<3.2	--	16.4	16.0	-2.5
Lead, µg/L (01049)	<0.015	0.045	--	0.0238	<0.015	--	<0.015	<0.015	--	<0.015	<0.015	--	0.020	0.016	-22.2
Manganese, µg/L (01056)	2.37	2.46	3.7	76.6	71.7	-6.6	1.63	1.55	-5.0	3.14	3.23	2.8	3.18	3.23	1.6
Nickel, µg/L (01065)	0.22	0.23	4.4	6	5.7	-5.1	0.27	0.27	0.0	0.21	0.22	4.7	0.37	0.34	-8.5
Strontium, µg/L (01080)	56.7	56.6	-0.2	59.3	58.8	-0.8	21.9	22.1	0.9	33.1	32.6	-1.5	72.2	71.3	-1.3
Zinc, µg/L (01090)	<1.4	<1.4	--	9.9	8.4	-16.4	1.9	1.8	-5.4	<1.4	<1.4	--	<1.4	<1.4	--
Arsenic, µg/L (01000)	0.39	0.38	-2.6	0.23	0.17	-30.0	0.11	0.11	0.0	0.12	0.13	8.0	0.64	0.60	-6.5

Table 9*B*. Comparison of analytical results for samples collected by the equal-width-interval composite method (EWI) and single-point method, analyzed by the Pennsylvania Department of Environmental Protection Laboratory.

[EWI, equal-width-interval composite sample; SP, single dipped sample; positive % difference indicates result for SP sample is larger than EWI sample; deg C, degrees Celcius; f, filtered; uf, unfiltered; mg/L, milligrams per liter; µg/L, micrograms per liter; PA, Pennsylvania; --, could not compare due to differences in lab detection limits; % Diff, percent difference; <, less than]

Constituent and USGS parameter code	Roaring Branch near Roaring Branch, PA			Lycoming Creek at Ralston, PA			Grays Run near fields station, PA			Pleasant Stream at Marsh Hill, PA			Mill Creek near Hepburnville, PA		
	8/1/2011 10:30 EWI	8/1/2011 11:45 SP	% Diff	8/1/2011 13:15 EWI	8/1/2011 14:00 SP	% Diff	8/2/2011 11:00 EWI	8/2/2011 11:31 SP	% Diff	8/2/2011 08:30 EWI	8/2/2011 09:01 SP	% Diff	8/2/2011 13:00 EWI	8/2/2011 13:31 SP	% Diff
Dissolved solids dried at 180 degrees Celsius, f, mg/L (70300)	74	70	-5.6	78	78	0.0	30	34	12.5	40	30	-28.6	126	136	14.7
Calcium, uf, mg/L (00916)	12	12	0.0	11	11	0.0	4.2	4.3	2.4	6	5.8	-3.4	20	20	0.0
Magnesium, uf, mg/L (00925)	2.1	1.9	-10.0	3	3	0.0	0.9	0.9	0.0	1.1	1.1	0.0	4.2	4.2	0.0
Bromide, uf, mg/L (63689)	<0.2	<0.2	--	<0.2	<0.2	--	<0.2	<0.2	--	<0.2	<0.2	--	<0.2	<0.2	--
Chloride, uf, mg/L (99220)	5.5	5.7	3.6	5.3	5.8	9.0	1.0	1.1	9.5	1.3	1.2	-8.0	19	19	0.0
Sulfate, uf, mg/L (00946)	<15.0	<15.0	--	21	23.2	10.0	<15.0	<15.0	--	<15.0	<15.0	--	<15.0	<15.0	--
Phosphorus, f, mg/L as phosphorus (00666)	0.01	0.01	0.0	<0.010	0.01	--	<0.010	<0.010	--	<0.010	<0.010	--	0.022	0.024	16.7
Aluminum, f, µg/L (01106)	<200	<200	--	<200	<200	--	<200	<200	--	<200	<200	--	<200	<200	--
Barium, uf, µg/L (01007)	34	34	0.0	40	41	2.5	22	24	8.7	27	17	-45.5	43	45	8.9
Cadmium, f, µg/L (01025)	<0.2	<0.2	--	<0.2	<0.2	--	<0.2	<0.2	--	<0.2	<0.2	--	<0.2	<0.2	--
Chromium, uf, µg/L (01034)	<50	<50	--	<50	<50	--	<50	<50	--	<50	<50	--	<50	<50	--
Copper, f, µg/L (01040)	<4	<4	--	<4	<4	--	<4	<4	--	<4	<4	--	<4	<4	--
Iron, f, µg/L (01046)	<20	<20	--	<20	<20	--	<20	<20	--	<20	<20	--	<20	<20	--
Lead, f, µg/L (01049)	<1	<1	--	<1	<1	--	<1	<1	--	<1	<1	--	<1	<1	--
Manganese, uf, µg/L (01055)	<10	<10	--	90	90	0.0	<10	<10	--	<10	<10	--	<10	<10	--
Nickel, f, µg/L (01065)	<4	<4	--	6.1	6.1	0.0	<4	<4	--	<4	<4	--	<4	<4	--
Strontium, uf, µg/L (01082)	50	50	0.0	60	60	0.0	20	20	0.0	30	30	0.0	70	70	0.0
Zinc, f, µg/L (01090)	<5	7	--	10	10	0.0	7	6	-15.4	6	<5	--	7	6	-33.3
Arsenic, f, µg/L (01000)	<3	<3	--	<3	<3	--	<3	<3	--	<3	<3	--	<3	<3	--

Surface-Water Quality, August 1–3, 2011

Analytical results for samples of base flow in surface water in the Lycoming Creek watershed sampled at 31 sites during August 1–3, 2011, are given in tables 10–13 (at the back of the report); results are also available online in the USGS NWIS (U.S. Geological Survey, 2017). Those results are summarized and discussed in relation to drinking-water standards, spatial differences, and factors affecting the water quality.

Comparison to Standards and Range of Concentrations

The results of the water samples are compared to EPA drinking-water standards and other guidelines, and the range of concentrations is given in table 14. Drinking water metrics are used for comparison because the surface water in Lycoming Creek is a source of water that may be captured by production wells as source of public drinking-water supply. The EPA has determined maximum contaminant levels (MCLs) that establish the maximum amount of a given constituent that is allowed in public drinking water (U.S. Environmental Protection Agency, 2016). Secondary maximum contaminant levels (SMCLs) were also established by EPA as guidelines for managing aesthetic considerations, such as taste, color, and odor. For some constituents that do not have an MCL or SMCL, a nonregulatory health-based screening level (HBSL) is listed in table 14. The HBSL is used by the USGS National Water-Quality Assessment Project to show water-quality results in a human-health context (Toccalino and others, 2012).

The concentrations of constituents analyzed for the water sample from the main stem of Lycoming Creek at 3rd Street Bridge (site 31) met the respective drinking water standards or screening levels. This sample represents water in Lycoming Creek nearest to the Lycoming Creek well field where water from the creek could be a source of water to the wells. None of the concentrations measured for other samples of surface water from the main stem or tributaries of Lycoming Creek failed to meet any of the MCLs for drinking water; however, concentrations for some constituents at a few sites in the watershed were outside of acceptable SMCL or HBSL ranges (table 15).

Major Constituents and Physical Properties

Of the major constituents and physical properties analyzed, none failed to meet the MCL and only pH and sodium were outside of acceptable SMCL or HBSL ranges. The pH was measured in the field at 20 sites by USGS and was found to be less than the minimum SMCL value of 6.5 at ten of those sites (table 15). Samples from 11 surface-water sites sampled by PaDEP were sent to the PaDEP laboratory for pH determination, but comparison of the field and laboratory values showed that the laboratory value was substantially greater than the field value, and was probably not representative of the pH in the stream. The 10 low values of field pH are related to past coal mining and acid deposition on watersheds having little natural buffering capacity. The low pH is not a health concern, but acidic water can mobilize trace metals that do have health-based standards. The sodium concentration was analyzed in samples from 31 surface-water sites. The HBSL for sodium of 20 mg/L was exceeded at one sample site. The sodium concentration in the sample from Bottle Run (site 30) of 25.8 mg/L (table 15) failed to meet the HBSL for individuals on sodium-restricted diets.

The range of concentrations found in surface-water samples for the other major constituents that met the drinking water standard or guideline are also listed in table 14 and illustrated with boxplots for some constituents in figure 9. Concentrations of all constituents ranged over at least one order of magnitude, with chloride having the largest range from 0.3 to 45.4 mg/L. The lowest values of acid neutralizing capacity were zero for the acidic waters in Dutchman Run (site 8) and 0.6 mg/L for Red Run at Ralston (site 7). The dissolved solids concentration was less than the laboratory reporting level of 12 mg/L for the sample from Wolf Run near Trout Run (site 21), indicating water with remarkably few dissolved solids.

Trace Constituents

The concentrations of trace constituents ranged widely in the surface-water samples from Lycoming Creek watershed. Of the 22 trace metals included in the analysis; only silver was a nondetect in all of the samples. The trace constituents detected at every site in the watershed were aluminum, arsenic, barium, boron, lithium, manganese, nickel, selenium, and strontium. Other constituents that were found in at least half of the sites include antimony, beryllium, bromide, cobalt, fluoride, iron, lead, molybdenum, and zinc. Other metals that were detected at less than half the sites include cadmium, chromium, and copper. The range in concentration of trace constituents in samples from Lycoming Creek watershed was generally greater than for the major constituents. Concentrations of aluminum, cobalt, and manganese ranged over at least three orders of magnitude in samples, and concentrations of beryllium, iron, lead, lithium, nickel, and zinc ranged over at least two orders of magnitude.

Of the 22 trace constituents analyzed, only concentrations of aluminum, manganese, and iron were outside acceptable SMCL ranges in one or more surface-water samples (table 15). Guidelines for these constituents are given because concentrations not meeting the standard can impart an objectionable water color, staining, or metallic taste. The SMCL of 50 µg/L for both aluminum and manganese was exceeded at sites on Dutchman Run (site 8), Red Run near Ralston (site 7), and Lycoming Creek at Ralston (site 9). The SMCL was also exceeded for aluminum in Frozen Run (site 13) and

Table 14. Minimum, median, and maximum values for major constituents, trace constituents, nutrients, and radiochemicals for surface-water samples from the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.

[mg/L, milligrams per liter; µg/L, micrograms per liter; mg/L as $CaCO_3$, milligrams per liter as calcium carbonate; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; SiO_2, silica; --, no data or not applicable; MCL, maximum contaminant level; HBSL, health based screening level; TT, treatment technology; SMCL, secondary maximum contaminant level]

Constituent[1]	Unit	Number and (percent) above reporting level	Summary of results			Number and (percent) exceeding lowest standard or screening level	Drinking water standard or screening level		
			Minimum	Median	Maximum		MCL or TT[2]	HBSL[3]	SMCL[2]
Major constituents									
Calcium (00915, 00910)	mg/L	31(100)	1.8	10.0	24.6	--	--	--	--
Magnesium (00925, 00927)	mg/L	31(100)	0.6	2.0	9.79	--	--	--	--
Potassium (00935)	mg/L	20(100)	0.32	0.96	2.24	--	--	--	--
Sodium (00930)	mg/L	20(100)	0.58	1.47	25.8	1(5)	--	20	30
Acid neutralizing capacity, as $CaCO_3$ (00419, 00417)	mg/L	31(100)	0.0	21.0	66	--	--	--	--
Chloride (00940, 99220)	mg/L	31(100)	0.3	3.8	45.4	0(0)	--	--	250
Sulfate (00945)	mg/L	20(100)	4.90	6.98	130	0(0)	--	--	250
Dissolved solids dried at 180°C (70300)	mg/L	29(93.5)	<12	66.0	202	0(0)	--	--	500
Hardness, as $CaCO_3$ (00900, 00907)	mg/L	31(100)	6.8	33.0	89.5	--	--	--	--
pH field (00400)	--	20(100)	2.8	6.4	8.1	10(50)[a]	--	--	6.5<x<8.5
Silica as SiO_2 (00955)	mg/L	20(100)	1.18	4.84	20.7	--	--	--	--
Specific conductance, laboratory, µS/cm at 25°C (90095)	µS/cm	31(100)	27.0	102.0	420	--	--	--	--
Trace constituents									
Aluminum(01106)	µg/L	20(100)	2.4	5.7	4,950	4(25)	--	--	50–200
Antimony (01095)	µg/L	11(55)	<0.027	0.035	0.092	0(0)	6	--	--
Arsenic (01000)4	µg/L	16(80)	<0.15	0.21	0.67	0(0)	10	--	--
Barium (01005, 01007)	µg/L	31(100)	14.2	30.3	81.1	0(0)	2,000	--	--
Beryllium (01010)	µg/L	11(55)	<0.006	0.01	3.38	0(0)	4	--	--
Boron (01020)	µg/L	20(100)	3.90	6.10	15	0(0)	--	1,000	--
Bromide (71870)	mg/L	10(50)	<0.010	<0.010	0.038	--	--	--	--
Cadmium (01025)	µg/L	5(25)	<0.006	<0.006	0.5	0(0)	5	--	--
Chromium (01030)	µg/L	9(45)	<0.06	<0.06	1.00	0(0)	100	--	--
Cobalt (01035)[4]	µg/L	4(25)	<0.39	<0.39	45.1	--	--	--	--
Copper (01040)	µg/L	6(30)	<0.50	<0.50	20.5	0(0)	1,300	--	1,000
Fluoride (00950)	mg/L	10(50)	<0.04	<0.04	0.089	0(0)	4	--	2

Table 14. Minimum, median, and maximum values for major constituents, trace constituents, nutrients, and radiochemicals for surface-water samples from the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[mg/L, milligrams per liter; µg/L, micrograms per liter; mg/L as $CaCO_3$, milligrams per liter as calcium carbonate; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; SiO_2, silica; --, no data or not applicable; MCL, maximum contaminant level; HBSL, health based screening level; TT, treatment technology; SMCL, secondary maximum contaminant level]

Constituent[1]	Unit	Number and (percent) above reporting level	Summary of results			Number and (percent) exceeding lowest standard or screening level	Drinking water standard or screening level		
			Minimum	Median	Maximum		MCL or TT[2]	HBSL[3]	SMCL[2]
Iron (01046)	µg/L	16(80)	<3.2	3.40	498	1(5)	--	--	300
Lead (01049)	µg/L	12(60)	<0.015	0.02	4.06	0(0)	15	--	--
Lithium (01130)	µg/L	20(100)	0.26	0.57	49.2	--	--	--	--
Manganese (01056)[4]	µg/L	17(85)	<0.85	3.16	1,770	4(20)	--	300	50
Molybdenum (01060)	µg/L	15(75)	<0.014	0.03	0.177	0(0)	--	40	--
Nickel (01065)	µg/L	20(100)	0.12	0.46	90.2	0(0)	--	100	--
Selenium (01145)	µg/L	20(100)	0.04	0.05	0.83	0(0)	50	--	--
Silver (01075)	µg/L	0(0)	<0.005	<0.005	<0.005	0(0)	--	--	100
Strontium (01080, 01082)	µg/L	31(100)	17.0	50.0	120	0(0)	--	4,000	--
Zinc (01090)	µg/L	17(54.8)	<1.4	1.9	190	0(0)	--	--	5,000
Nutrients									
Ammonia as nitrogen (00608, 00610)	mg/L	3(9.7)	<0.01	<0.01	0.0600	0(0)	--	30	--
Nitrite nitrogen (00613)	mg/L	7(35)	<0.001	<0.001	0.0092	0(0)	1	--	--
Orthophosphate as phosphorus (00671)	mg/L	10(50)	<0.004	<0.004	0.032	--	--	--	--
Total nitrogen (00600)	mg/L	17(85)	0.16	0.29	1.8	--	--	--	--
Nitrate, as nitrogen (00618, 00620)	mg/L	31(100)	0.05	0.3	1.55	0(0)	10	--	--
Phosphorus as phosphorus (00666, 00665)	mg/L	7(22.6)	<0.02	<0.02	0.036	--	--	--	--
Radiochemicals									
Uranium (22703)	µg/L	17(85)	<0.004	0.01	0.688	0(0)	30	--	--
Gross alpha radioactivity, 30 day count, Th-230 curve (62639)	pCi/L	2(10)	<0.20	<0.20	1.17	0(0)	15	--	--
Gross beta radioactivity, 30 day count, Cs-137 curve (62645)	pCi/L	8(40)	<0.70	<0.70	1.76	--	--	--	--

[1]Constituents are listed with the parameter code. Where two codes are listed, the first corresponds to the U.S. Geological Survey analysis for a filtered sample followed by the Pennsylvania Department of Environmental Protection analyis of the unfiltered sample. The number of environmental samples listed is the sum of the. The number of environmental samples listed is the sum of filtered and unfiltered samples.

[2]U.S. Environmental Protection Agency (2016).

[3]Toccalino and others (2012).

[4]Reporting level increased to five-times the concentration detected in the blank water sample for this constituent.

[a]pH was less than 6.5; no values were greater than 8.5.

Table 15. Surface-water sampling sites where a secondary maximum contaminant level (SMCL) or health based screening level (HBSL) for at least one constituent was not achieved in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.

[mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; HBSL, health based screening level; SMCL, secondary maximum contaminant level; PA, Pennsylvania; N, north; --, results were within acceptable rage for the constituent]

Site name	Analytical results for constitutents that did not meet the SMCL or HBSL for drinking water				
	pH (units)	Aluminum (µg/L)	Iron (µg/L)	Manganese (µg/L)	Sodium (mg/L)
	SMCL 6.5<pH<8.5	SMCL is 50	SMCL is 300	SMCL is 50	HBSL is 20
Lycoming Creek near Dogtown, PA	5.4	--	--	--	--
Salt Spring Run near South Union, PA	5.6	--	--	--	--
Red Run at Ralston, PA	3.9	606	--	641	--
Dutchman Run near Ralston, PA	2.8	4,950	498	1,770	--
Lycoming Creek at Ralston, PA	--	75.7	--	76.6	--
Rock Run at McIntyre Township, PA	5.6	--	--	--	--
Hounds Run at McIntyre Township, PA	5.0	--	--	--	--
Frozen Run near Ralston, PA	4.9	59.1	--	--	--
Grays Run near Fields Station, PA	6.3	--	--	--	--
Trout Run at Route 15N at Lewis Township, PA	4.7	--	--	--	--
Wolf Run near Trout Run, PA	5.2	--	--	--	--
Bottle Run near Williamsport, PA	--	--	--	166	25.8

for manganese in Bottle Run (site 30). The SMCL for iron of 300 µg/L was exceeded at Dutchman Run. The relatively elevated concentrations of these trace metals are related to low pH at these sites, except for the sample collected in Bottle Run, which is the most urbanized tributary basin in the Lycoming Creek watershed.

Nutrients

Surface-water samples from the Lycoming Creek watershed were analyzed for total nitrogen, organic nitrogen, nitrate, nitrite, and ammonia, as well as phosphorus and orthophosphate. None of the species of nitrogen or phosphorus were found in concentrations failing to meet a drinking water standard or guideline (table 14). Elevated concentrations of nitrogen compounds can pose a hazard for human consumption, so an MCL has been established by EPA for nitrate (10 mg/L) and nitrite (1 mg/L) and a HBSL is available for ammonia (30 mg/L). Phosphate is not associated with human-health problems, but concentrations greater than 1 mg/L may affect coagulation processes at water-treatment facilities. Nationally, nitrogen and phosphorus compounds occur naturally at concentrations typically less than about 0.58 mg/L for nitrate and 0.034 for total phosphorus (Dubrovsky and others, 2010, p. 52). Higher concentrations may indicate contamination from a number of potential sources, such as domestic and municipal wastewater, fertilizer, animal manure, and storm-water runoff.

Nitrate was detected at levels above the laboratory reporting level in all 31 samples. The highest measured concentration of nitrate of 1.55 mg/L (as nitrogen) from the sample in Mill Creek near Hepburnville (site 27) is less than 20 percent of the MCL value. Concentrations of ammonia (as nitrogen) were detected in only 3 of 31 samples, with a maximum value of 0.06 mg/L (table 14). Ammonium and nitrite were found in low concentrations because they are reduced forms of nitrogen that are typically more stable in low-oxygen environments, while nitrate is oxidized and therefore more stable in these stream settings.

Orthophosphate concentrations above the reporting level of 0.004 mg/L were found in 10 of the 20 USGS sampling

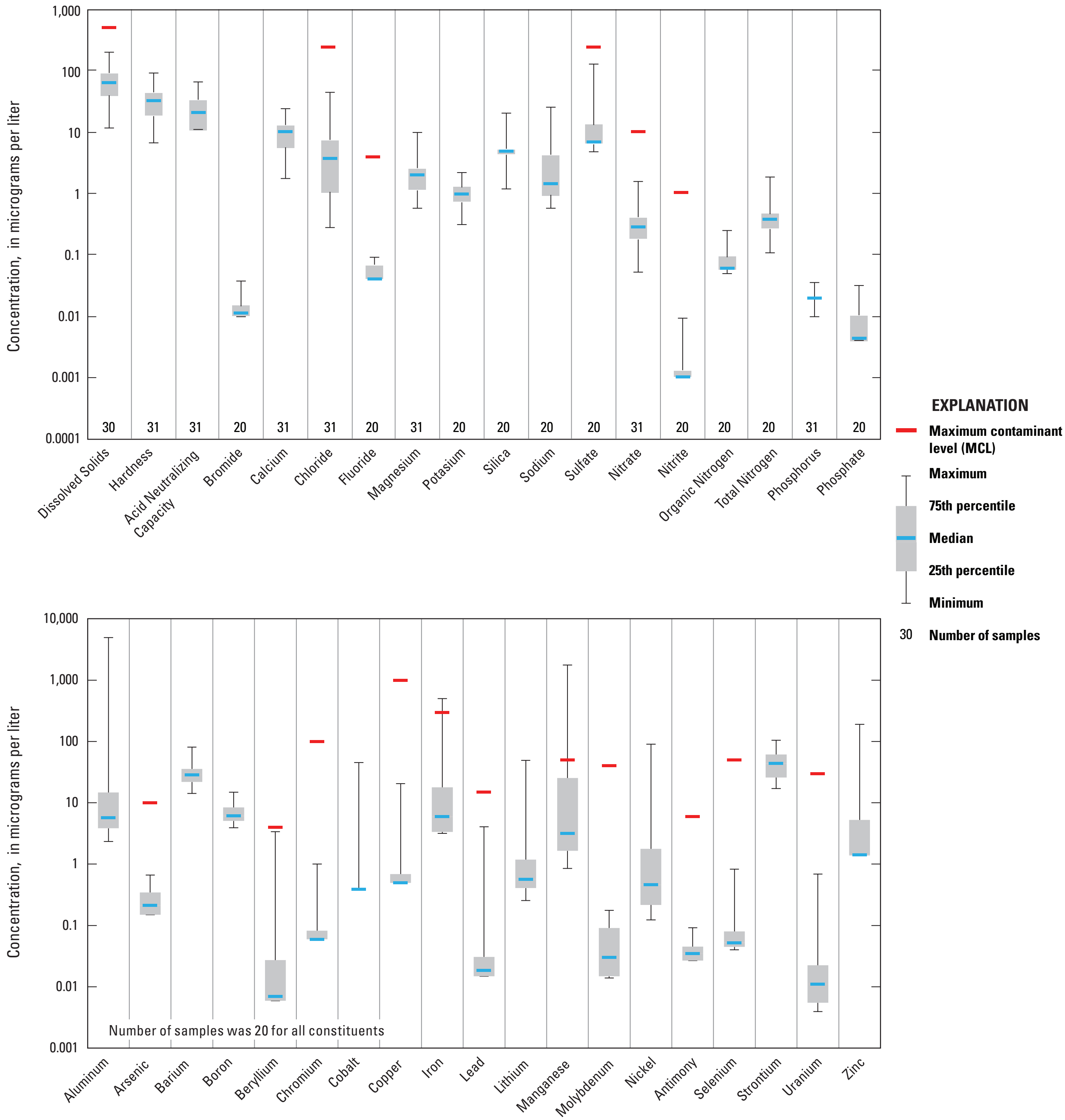


Figure 9. Comparison of concentrations for selected water-quality constituents in surface-water samples in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.

locations in the Lycoming Creek watershed. The reported concentrations were very low, ranging from 0.005 to 0.032 mg/L (as phosphorus), with a median value of 0.010 mg/L. Orthophosphate concentrations equal to or less than about 0.01 mg/L are within the range of national background levels (Dubrovsky and others, 2010, p. 52).

Radiochemicals

Radionuclides that are naturally present in soils and rocks may be dissolved and enter into surface water. Each radionuclide will emit alpha particles or beta particles while it undergoes radioactive decay. Surface-water samples from 20 sites were analyzed at the laboratory for gross alpha and gross beta radiation and total uranium. The highest gross alpha activity was 2.1 pCi/L, well within the acceptable range below the MCL of 15 pCi/L (table 11 at the end of the report). Uranium was present in 17 of the 20 samples and had a maximum value of 0.688 µg/L at Dutchman Run near Ralston (site 8), much less than the MCL of 30 µg/L (table 14).

Spatial Differences and Factors Affecting Water Quality

The quality of surface water is not uniform throughout the Lycoming Creek watershed. The Lycoming Creek watershed was divided into three parts—upper, middle, and lower—based on physiographic sections, which provides a useful way to discuss the major spatial differences in base-flow quality. The upper basin is mostly within the Glaciated Low Plateau Section of the Appalachian Plateaus Physiographic Province; the middle basin is within the Deep Valleys and Glaciated High Plateau Sections of the Appalachian Plateaus Physiographic Province; and the lower part is in the Susquehanna Lowland Section of the Valley and Ridge Physiographic Province (fig. 2). Many of the major differences in water quality among the tributary streams and along the main stem of Lycoming Creek can be attributed to differences in the geology and land use of the upper, middle, and lower parts of the watershed.

The geologic formations and land uses for sampling sites in the upper, middle, and lower parts of Lycoming Creek watershed are generalized in figure 10. The figure shows that bedrock geology and land use are related. The upper and lower parts of the Lycoming Creek watershed are partly underlain with siltstones and shales of the Lock Haven Formation and older formations and a substantial amount of land is used for agriculture, with some suburban/commercial development. The middle part of the watershed is underlain by the Huntley Mountain Formation and younger formations, which consist predominantly of resistant sandstones that create steep topography that is not well suited for agriculture or development. Land use in the middle part is also constrained because about 40 percent of the area is state forest or state game land, where access and use is controlled.

Water Types

The relative concentrations of major ions in the upper, middle, and lower parts of Lycoming Creek watershed are illustrated by the use of stiff diagrams and specific-conductance values for the 20 stream sites sampled by USGS (fig. 11). The pattern of the Stiff diagram is determined by the relative proportions of cations and anions, expressed in equivalent weight units, and the size is determined by the absolute concentrations. The thickness of the stream in figure 11 also illustrates the approximate relative magnitude of stream discharge measured at the time of sample collection.

Figure 11 shows that streams in the upper part of Lycoming Creek watershed have calcium-bicarbonate-type waters with specific conductance values from 89 to 128 µS/cm at 25 °C. Streams in the middle part of the watershed are characterized, in general, by waters with much lower dissolved solids (specific conductance generally less than 50 µS/cm) and a greater percentage of sulfate relative to other anions. Two streams in the middle part (Dutchman Run and Red Run) have specific conductance values greater than 100 µS/cm and sulfate is the predominant anion, probably because of past coal mining in these watersheds. Samples from streams in the lower part of the watershed show an increase in chloride concentration relative to the other anions when compared to samples from the upper and middle parts of the Lycoming Creek watershed.

Concentration Maps

Maps showing the spatial variability in concentrations for selected constituents are shown in figures 12A–J. The constituents selected for mapping were those that were analyzed by USGS and PaDEP at all 31 surface-water sites and had results greater than the laboratory reporting level (the larger level if the reporting levels differed) at six or more sites. The constituents mapped are dissolved solids, hardness, acid neutralizing capacity, chloride, barium, strontium, iron, zinc, and nitrate. A map for pH determined in the field is also presented for the 20 sites sampled by USGS.

Dissolved Solids

Concentrations of dissolved solids (analyzed by drying at 180 degrees Celsius) ranged from less than 12 to 202 mg/L (fig. 12*A*). In the upper part of the watershed, concentrations were fairly similar, mostly within 44 to 79 mg/L. Samples from streams in the middle part of the watershed showed the greatest differences, from the nearly pristine water (less than 12 mg/L) in Wolf Run (site 21) to the coal-mining affected water (191 mg/L) in Dutchman Run (site 8), indicating that differences in land use in this part of the basin can have a large influence on dissolved-solids concentrations. In general, however, most of the streams in the middle part of the watershed (12 of 18 sites) had water with low dissolved solids concentrations—less than 44 mg/L. The highest concentration

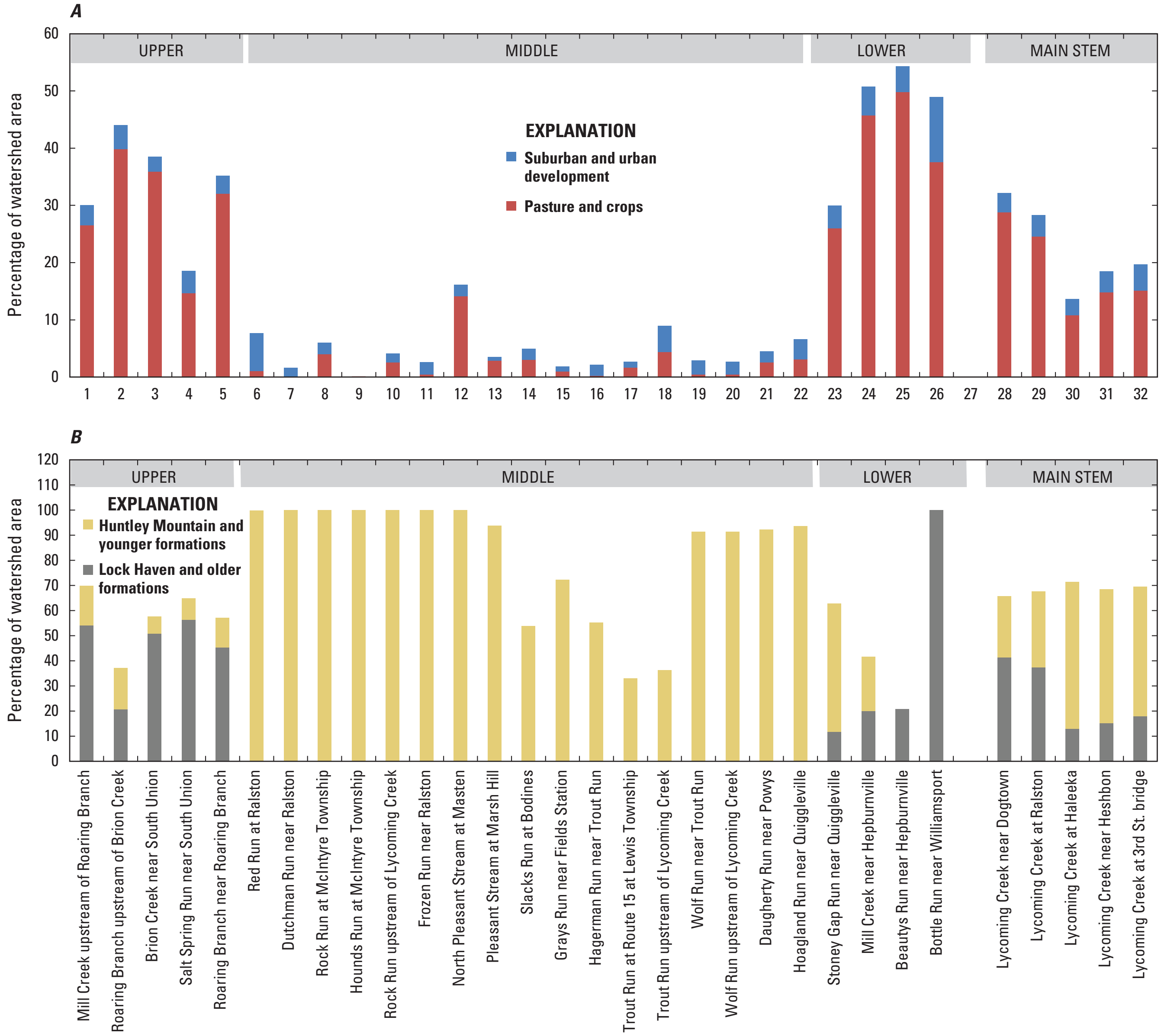


Figure 10. Percentage of the watershed area of selected (*A*) land uses and (*B*) geologic formations for tributary streams and sampling sites on the main stem of Lycoming Creek, in downstream order (left to right) from the upper, middle, and lower sections of Lycoming Creek watershed.

of 202 mg/L was from Bottle Run (site 30), which flows through an area of suburban/commercial development in the lower part of the study area near Williamsport. On the main stem of Lycoming Creek, concentrations of dissolved solids in five samples ranged from 66–96 mg/L. Concentrations were greatest at the most upstream site on Lycoming Creek near Dogtown (site 1) and lowest at the site near Heshbon Park (site 29). The low value at Heshbon Park is difficult to explain. Based on dilution from tributary inflows with low dissolved-solids concentrations from the middle part of the watershed, the main-stem site at Haleeka (site 24) would be expected to have the lowest dissolved-solids concentration. It is possible that this sample, the last one collected on August 3, was affected by the slight increase in stream discharge during the previous day (fig. 7).

Hardness

Concentrations of hardness ranged from 6.8 to 89.5 mg/L as calcium carbonate (fig. 12*B*). Water from all but four sites can be characterized as “soft” with hardness concentrations of less than 60 mg/L (Hem, 1985, p 159). Water sampled from the other four sites—Bottle Run (site 30), Beautys Run (site 28), Mill Creek near Hepburnville (site 27), and Dutchman Run (site 8)—is within the “moderately hard” category

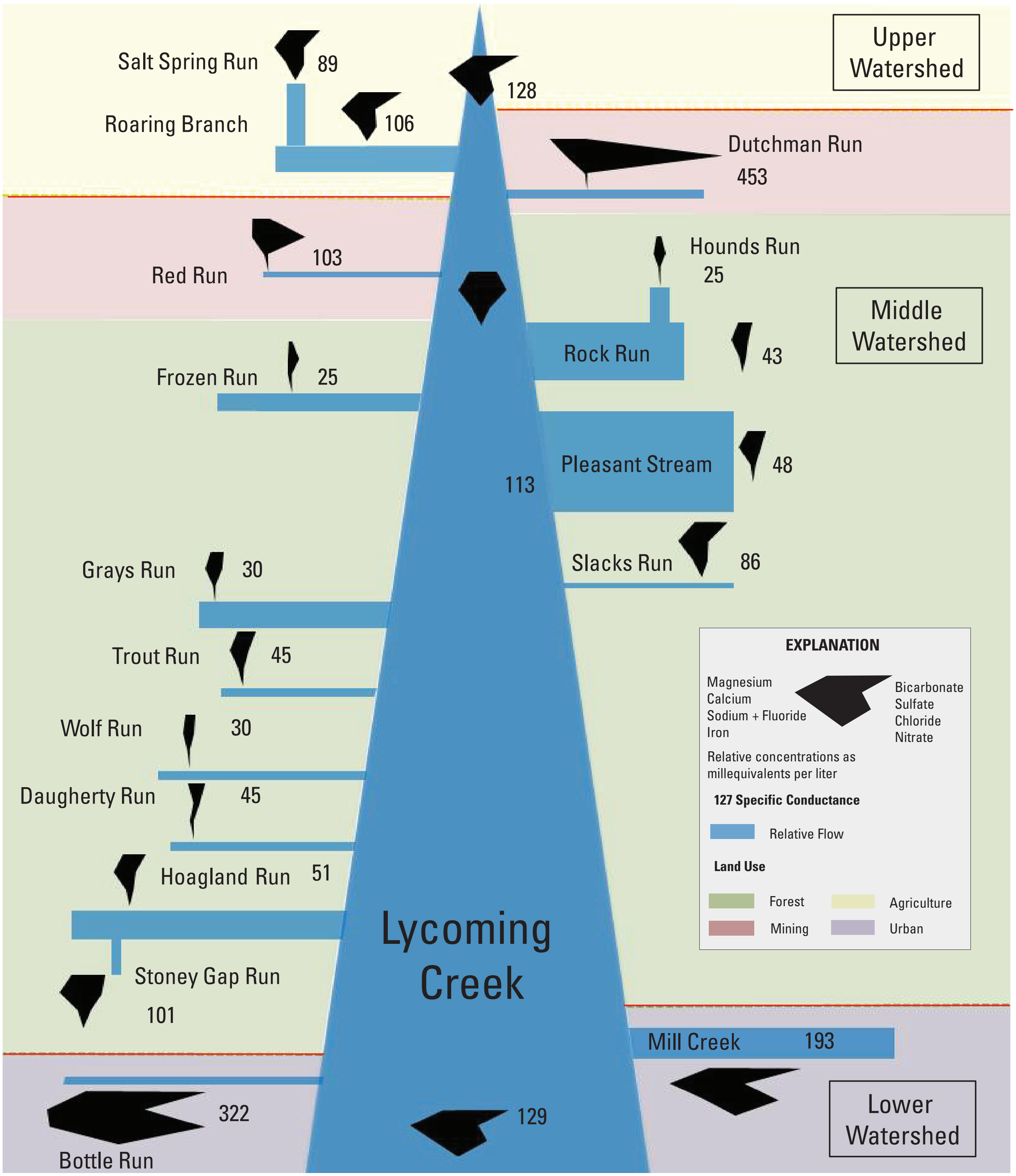


Figure 11. Stiff diagrams and specific-conductance values for 20 water samples collected by the U.S. Geological Survey in the Lycoming Creek watershed, August 1–3, 2011.

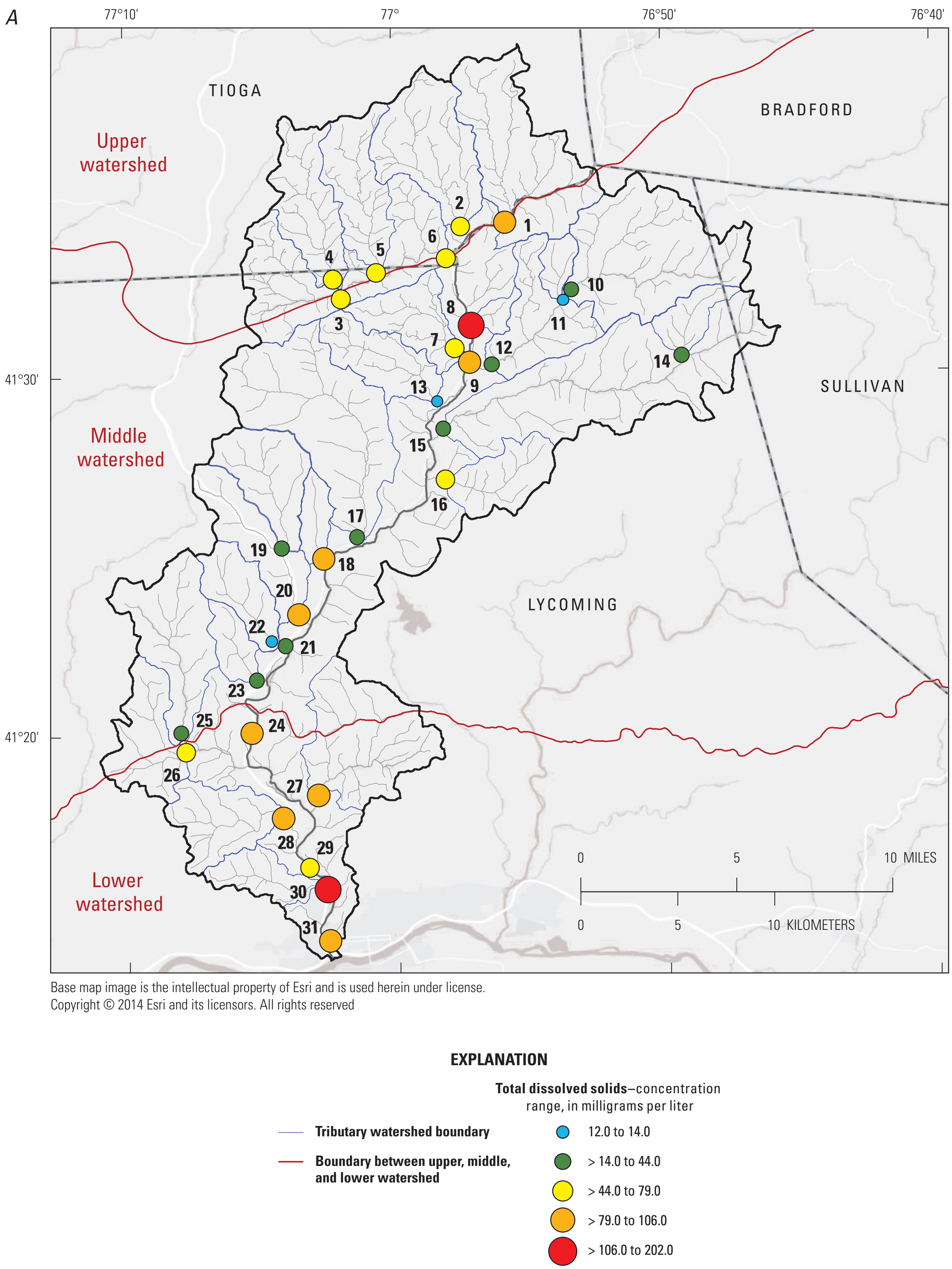


Figure 12*A*. Spatial variability for (*A*) total dissolved solids, (*B*) hardness, (*C*) acid neutralizing capacity, (*D*) chloride, (*E*) barium, (*F*) strontium, (*G*) iron, (H) zinc, (*I*) nitrate, and (*J*) field pH in the Lycoming Creek, Watershed, August 1–3, 2011. (Sites 1, 9, 24, 29, and 31 are on the main stem of Lycoming Creek)

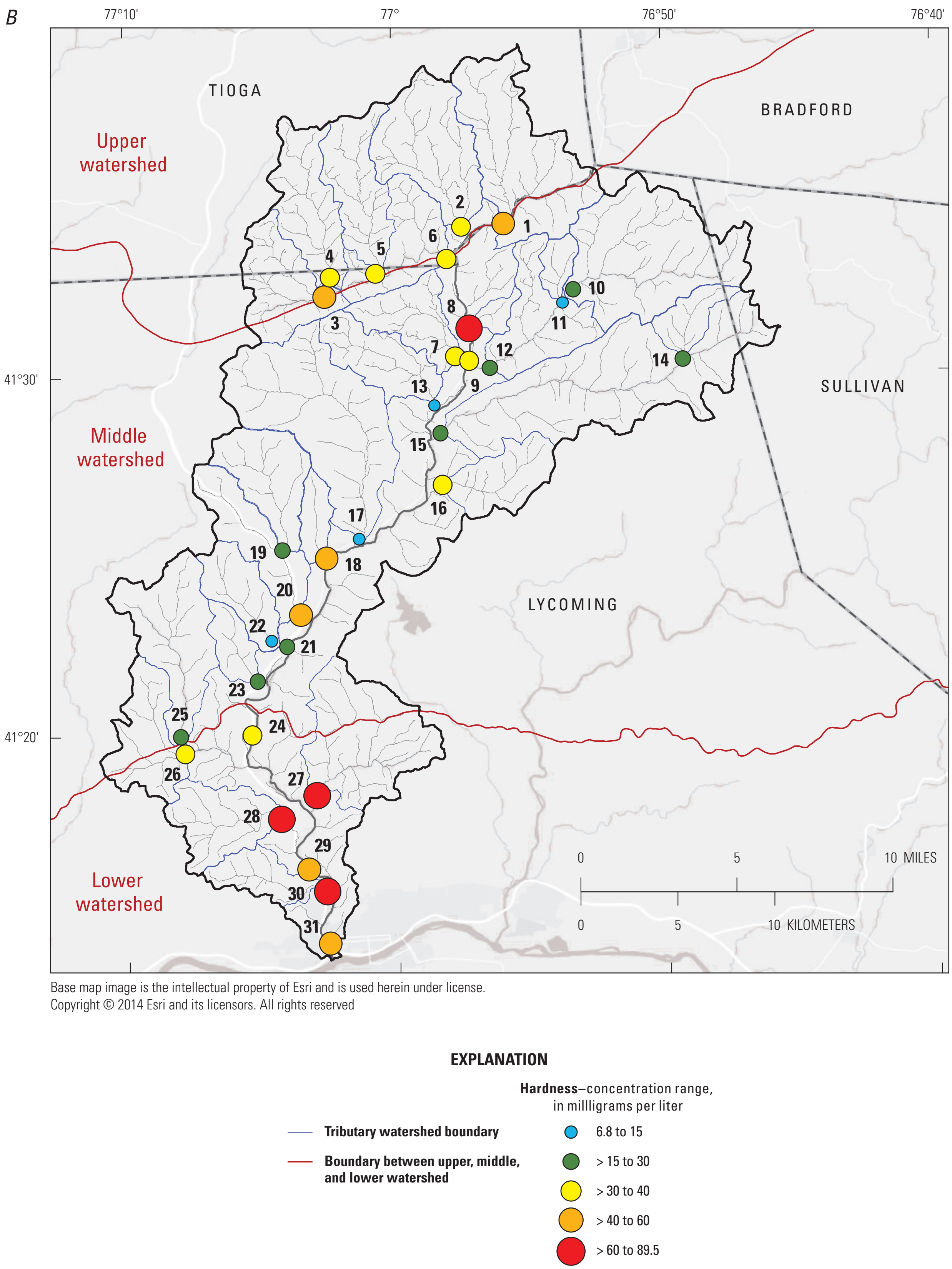
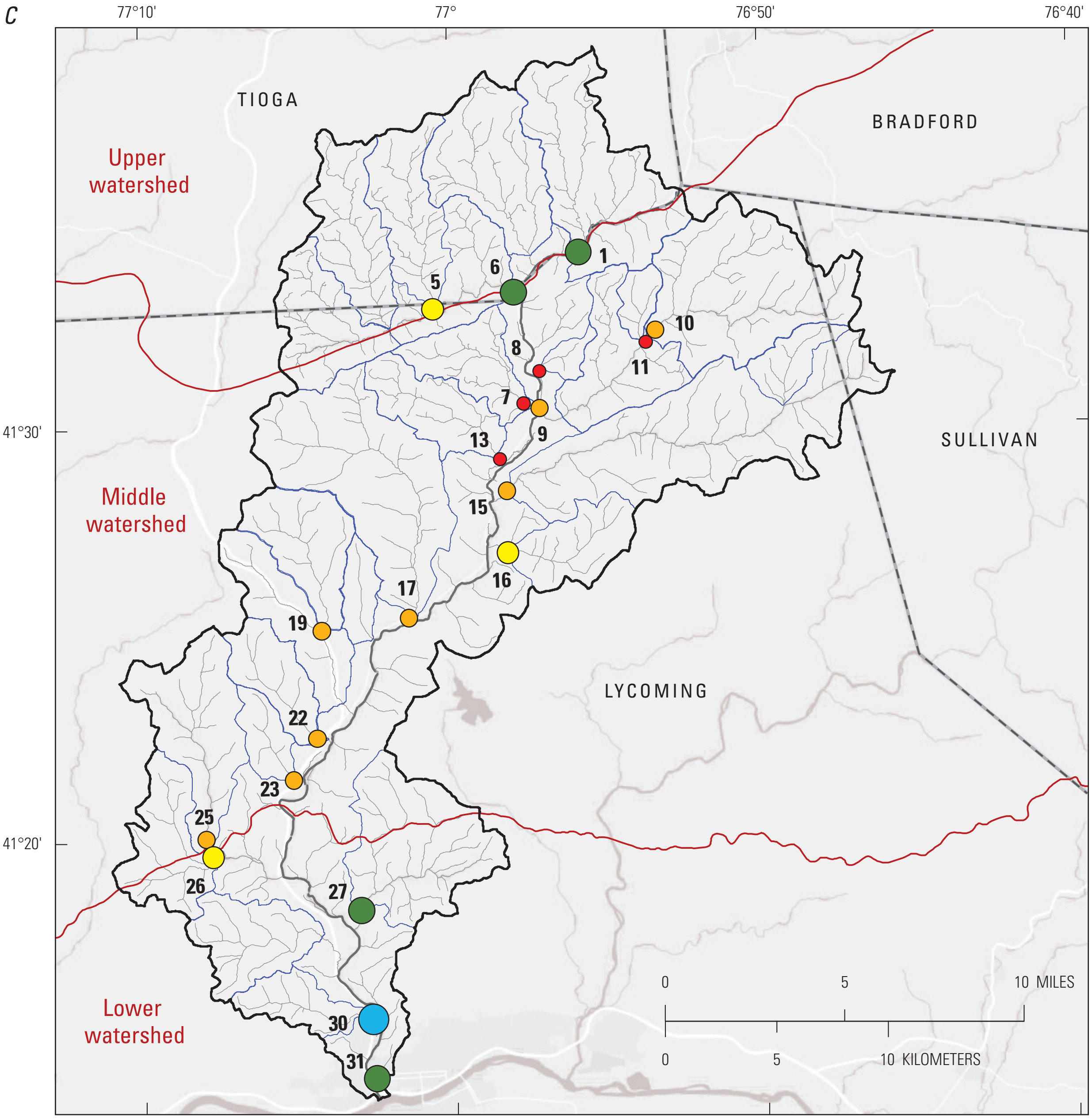


Figure 12*B*. Spatial variability for (*A*) total dissolved solids, (*B*) hardness, (*C*) acid neutralizing capacity, (*D*) chloride, (*E*) barium, (*F*) strontium, (*G*) iron, (H) zinc, (*I*) nitrate, and (*J*) field pH in the Lycoming Creek, Watershed, August 1–3, 2011. (Sites 1, 9, 24, 29, and 31 are on the main stem of Lycoming Creek)—Contuined



EXPLANATION

Acid neutralizing capacity—concentration range, in milligrams per liter

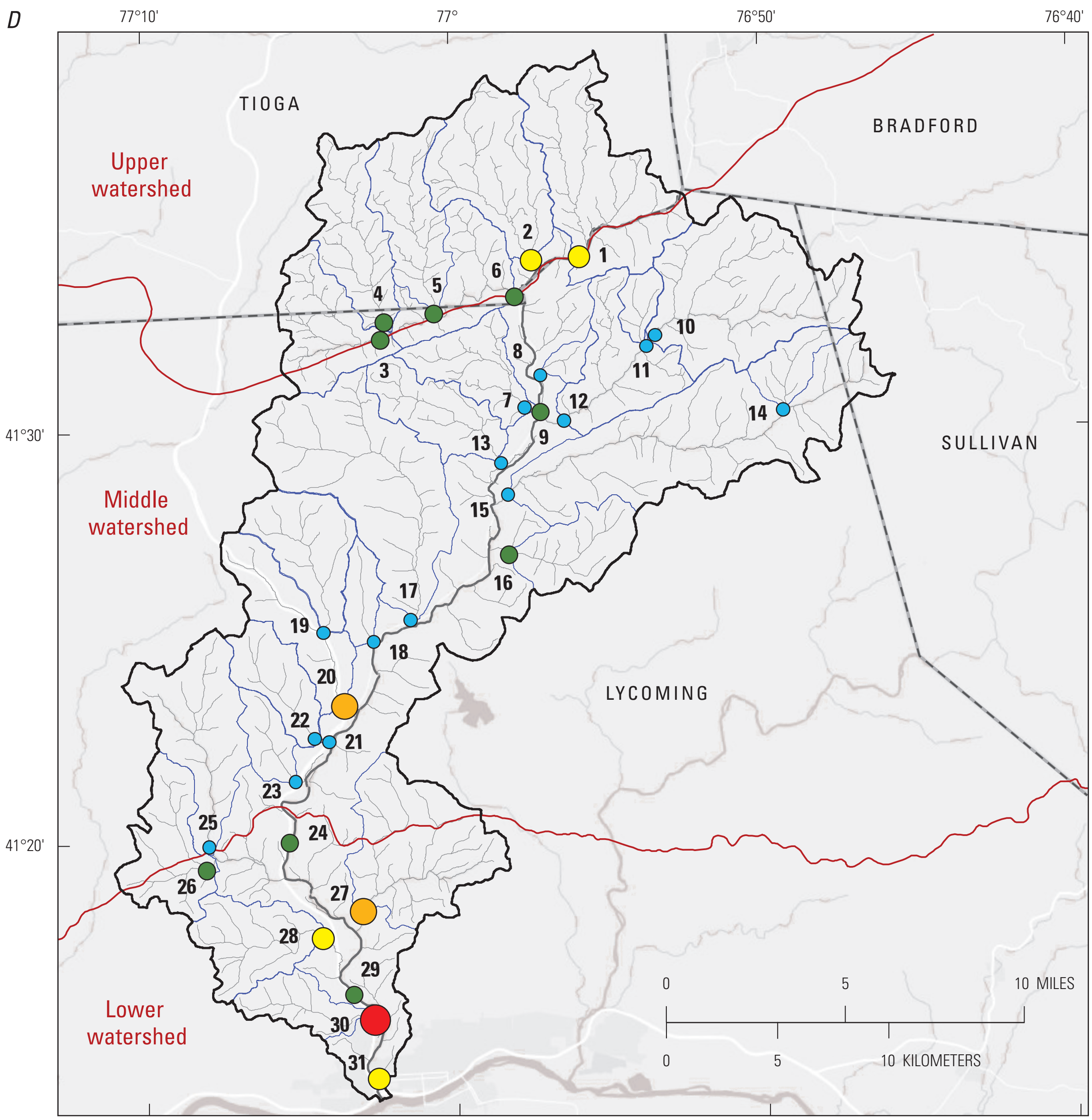
- 0.0 to 2.0
- > 2.0 to 18.0
- > 18.0 to 31.0
- > 31.0 to 45.0
- > 45.0 to 66.0

Tributary watershed boundary

Boundary between upper, middle, and lower watershed

Figure 12*C*. Spatial variability for (*A*) total dissolved solids, (*B*) hardness, (*C*) acid neutralizing capacity, (*D*) chloride, (*E*) barium, (*F*) strontium, (*G*) iron, (H) zinc, (*I*) nitrate, and (*J*) field pH in the Lycoming Creek, Watershed, August 1–3, 2011. (Sites 1, 9, 24, 29, and 31 are on the main stem of Lycoming Creek)—Contuined

D



EXPLANATION

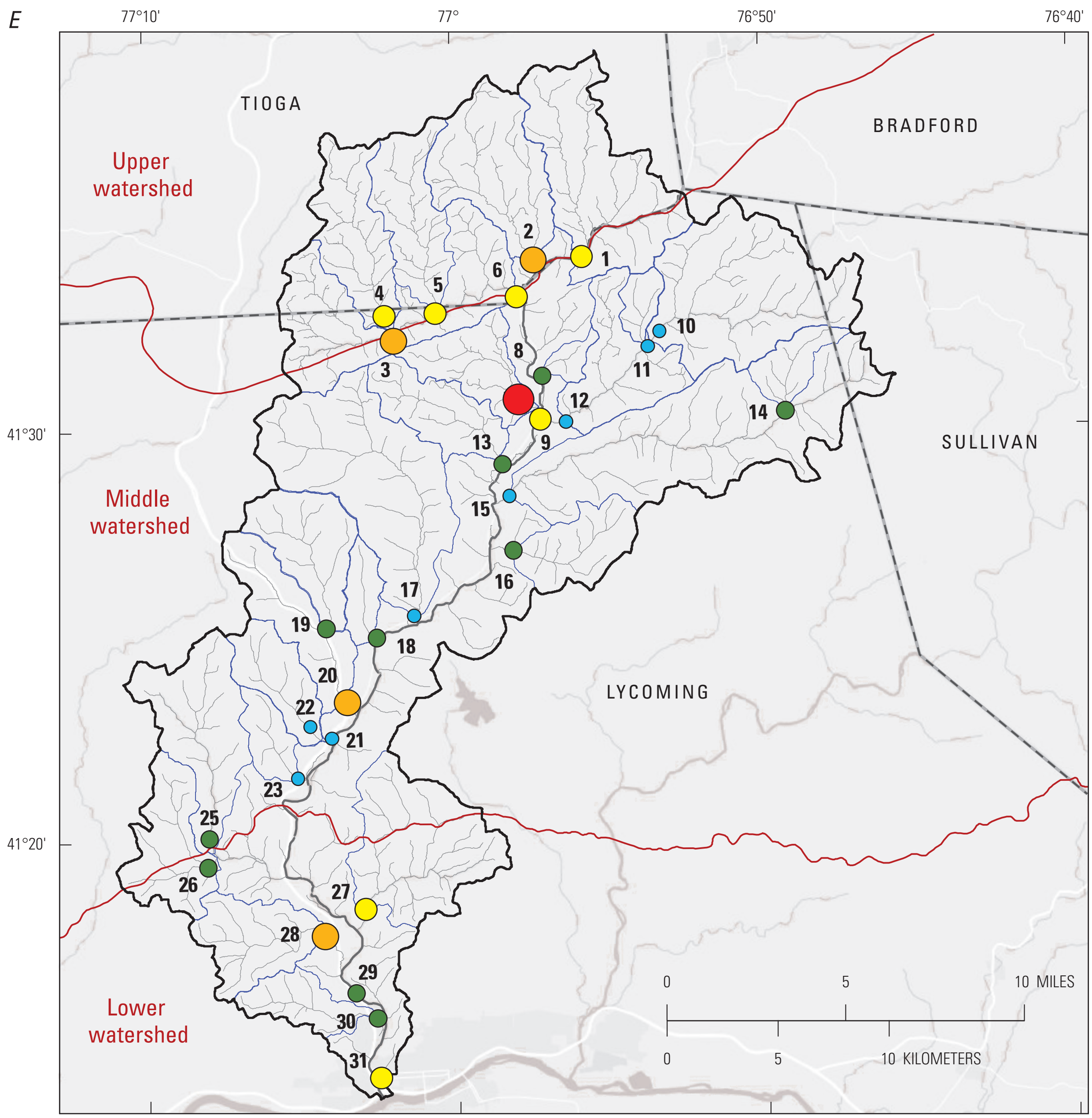
Tributary watershed boundary

Boundary between upper, middle, and lower watershed

Chloride—concentration range, in milligrams per liter

- 0.28 to 3.0
- > 3.0 to 7.9
- > 7.9 to 12.9
- > 12.9 to 20.3
- > 20.3 to 45.4

Figure 12*D*. Spatial variability for (*A*) total dissolved solids, (*B*) hardness, (*C*) acid neutralizing capacity, (*D*) chloride, (*E*) barium, (*F*) strontium, (*G*) iron, (H) zinc, (*I*) nitrate, and (*J*) field pH in the Lycoming Creek, Watershed, August 1–3, 2011. (Sites 1, 9, 24, 29, and 31 are on the main stem of Lycoming Creek)—Contuined



EXPLANATION

Tributary watershed boundary

Boundary between upper, middle, and lower watershed

Barium–concentration range, in micrograms per liter

- 14.2 to 23.0
- > 23.0 to 33.0
- > 33.0 to 41.9
- > 41.9 to 61.0
- > 61.0 to 81.1

Figure 12*E*. Spatial variability for (*A*) total dissolved solids, (*B*) hardness, (*C*) acid neutralizing capacity, (*D*) chloride, (*E*) barium, (*F*) strontium, (*G*) iron, (H) zinc, (*I*) nitrate, and (*J*) field pH in the Lycoming Creek, Watershed, August 1–3, 2011. (Sites 1, 9, 24, 29, and 31 are on the main stem of Lycoming Creek)—Contuined

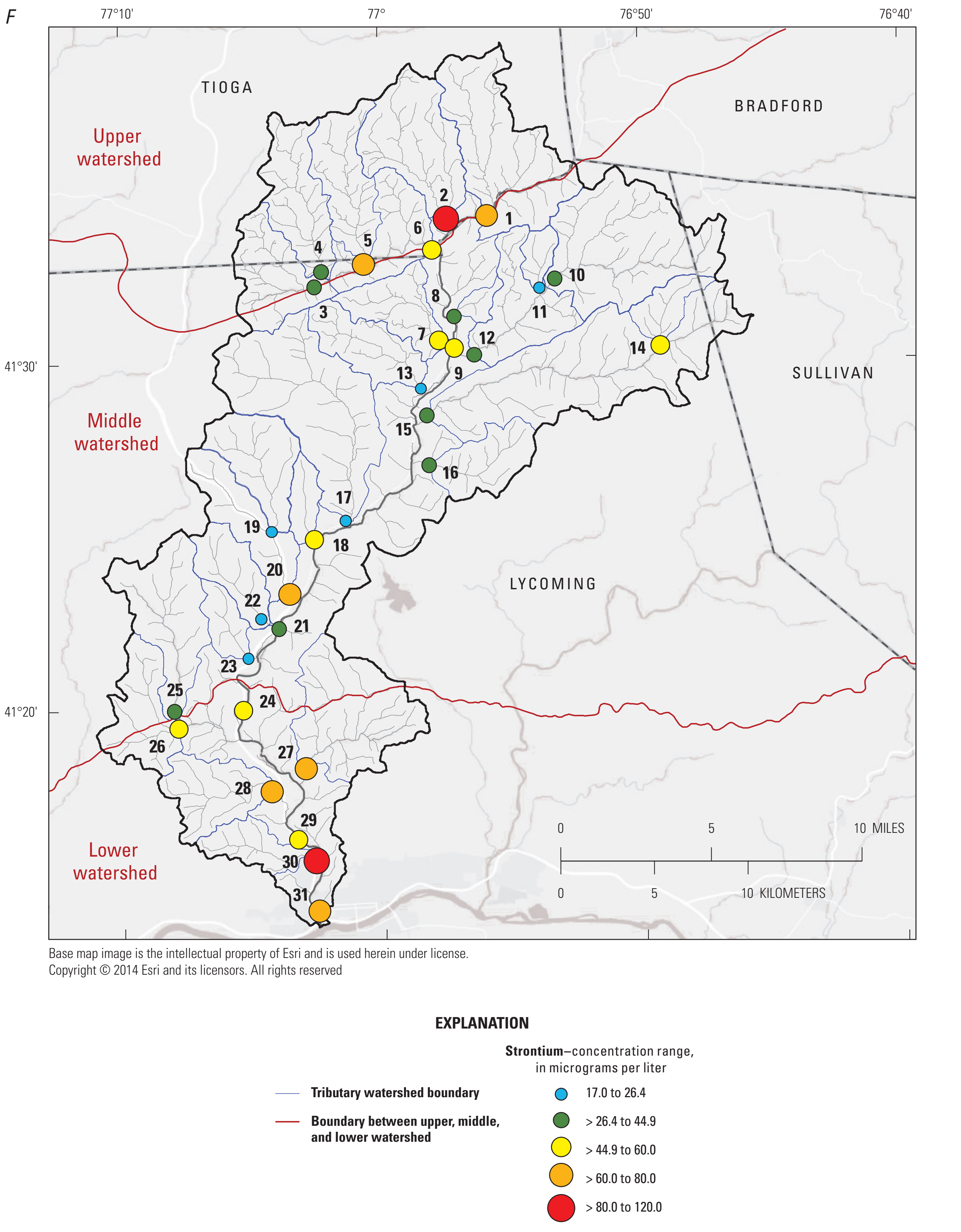


Figure 12*F*. Spatial variability for (*A*) total dissolved solids, (*B*) hardness, (*C*) acid neutralizing capacity, (*D*) chloride, (*E*) barium, (*F*) strontium, (*G*) iron, (H) zinc, (*I*) nitrate, and (*J*) field pH in the Lycoming Creek, Watershed, August 1–3, 2011. (Sites 1, 9, 24, 29, and 31 are on the main stem of Lycoming Creek)—Contuined

G

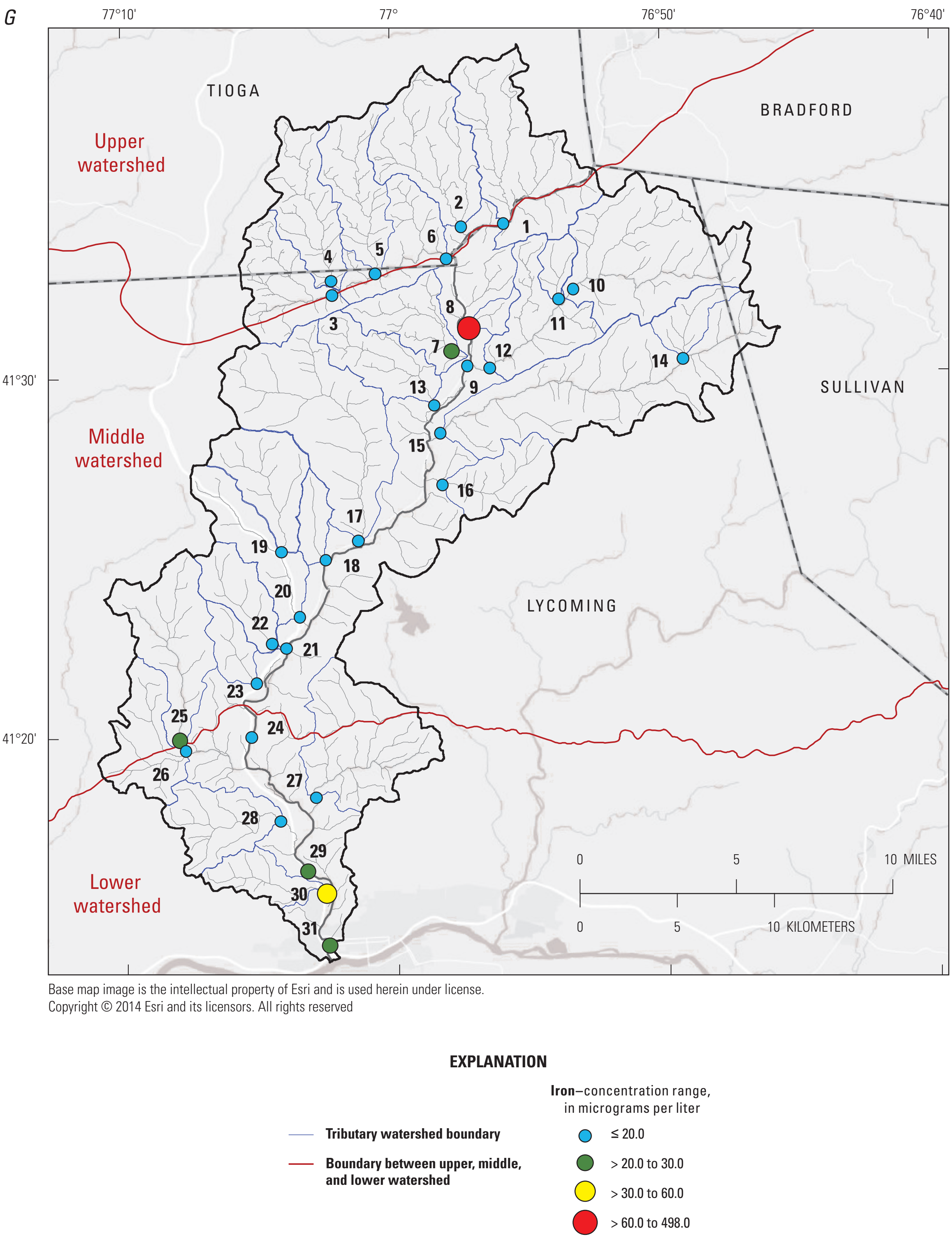
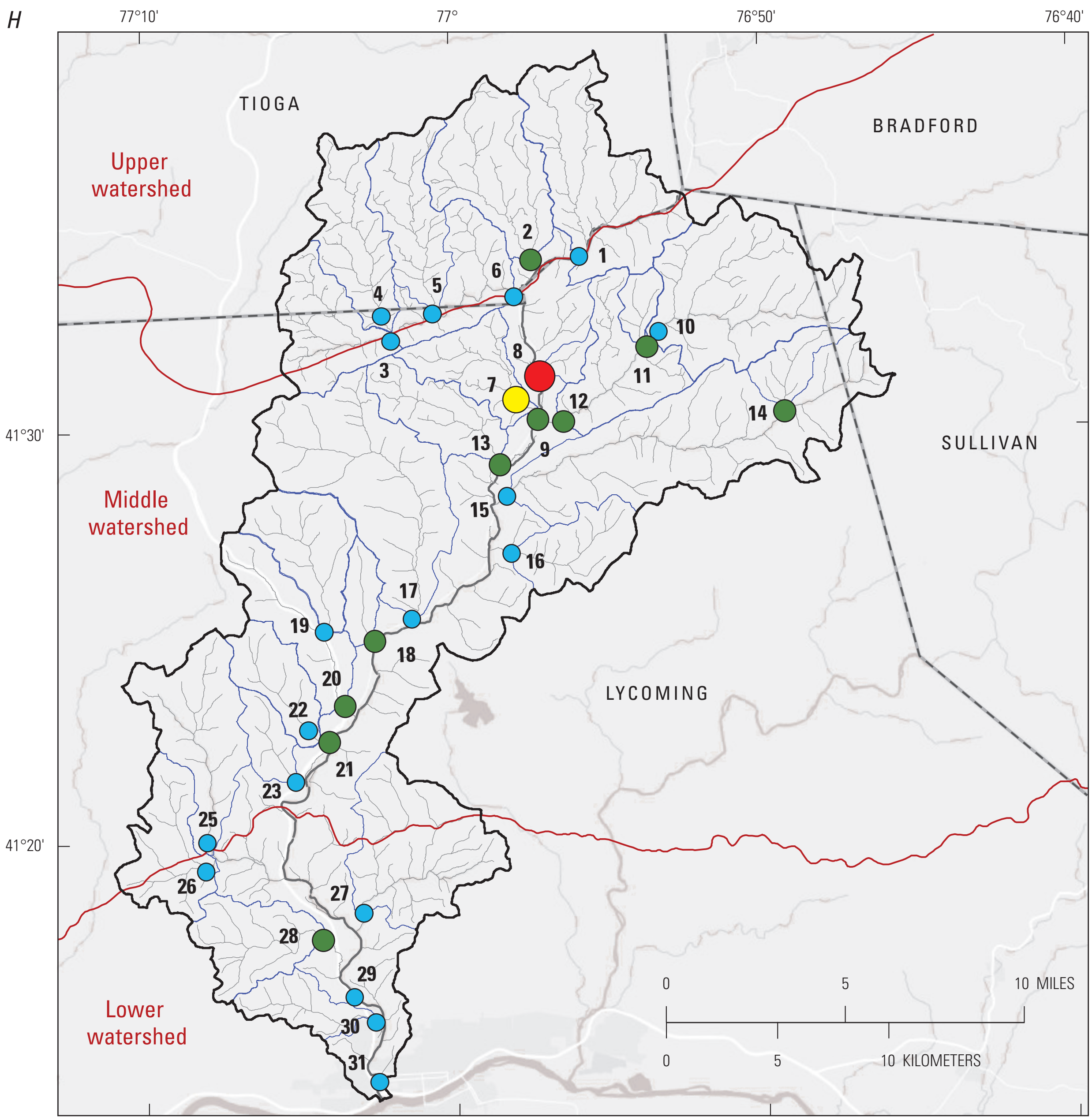


Figure 12*G*. Spatial variability for (*A*) total dissolved solids, (*B*) hardness, (*C*) acid neutralizing capacity, (*D*) chloride, (*E*) barium, (*F*) strontium, (*G*) iron, (H) zinc, (*I*) nitrate, and (*J*) field pH in the Lycoming Creek, Watershed, August 1–3, 2011. (Sites 1, 9, 24, 29, and 31 are on the main stem of Lycoming Creek)—Contuined



EXPLANATION

Tributary watershed boundary

Boundary between upper, middle, and lower watershed

Zinc—concentration range, in micrograms per liter

- ≤ 5.0
- > 5.0 to 20.0
- > 20.0 to 100.0
- > 100.0 to 190.0

Figure 12*H*. Spatial variability for (*A*) total dissolved solids, (*B*) hardness, (*C*) acid neutralizing capacity, (*D*) chloride, (*E*) barium, (*F*) strontium, (*G*) iron, (H) zinc, (*I*) nitrate, and (*J*) field pH in the Lycoming Creek, Watershed, August 1–3, 2011. (Sites 1, 9, 24, 29, and 31 are on the main stem of Lycoming Creek)—Contuined

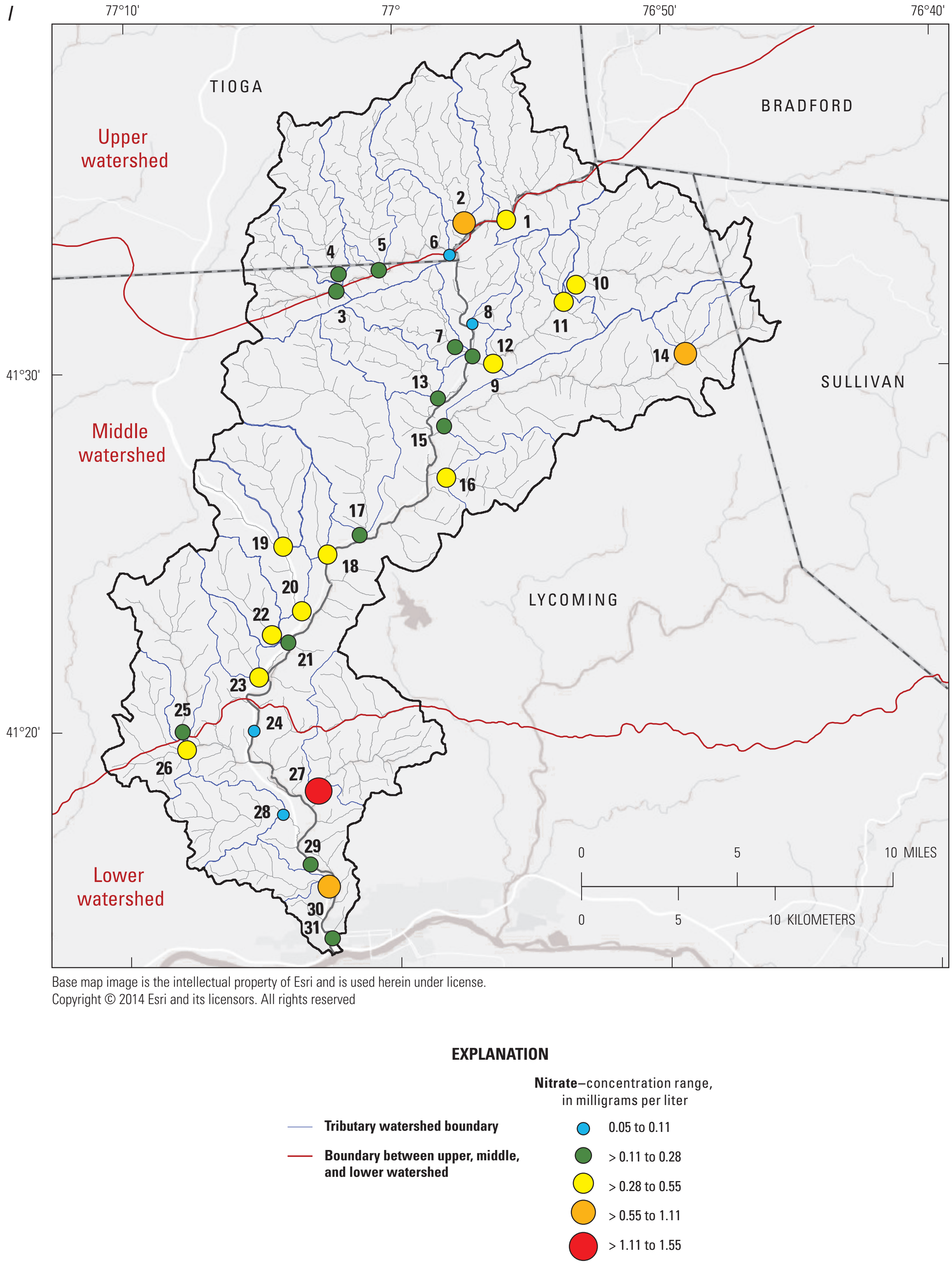


Figure 12*I*. Spatial variability for (*A*) total dissolved solids, (*B*) hardness, (*C*) acid neutralizing capacity, (*D*) chloride, (*E*) barium, (*F*) strontium, (*G*) iron, (H) zinc, (*I*) nitrate, and (*J*) field pH in the Lycoming Creek, Watershed, August 1–3, 2011. (Sites 1, 9, 24, 29, and 31 are on the main stem of Lycoming Creek)—Contuined

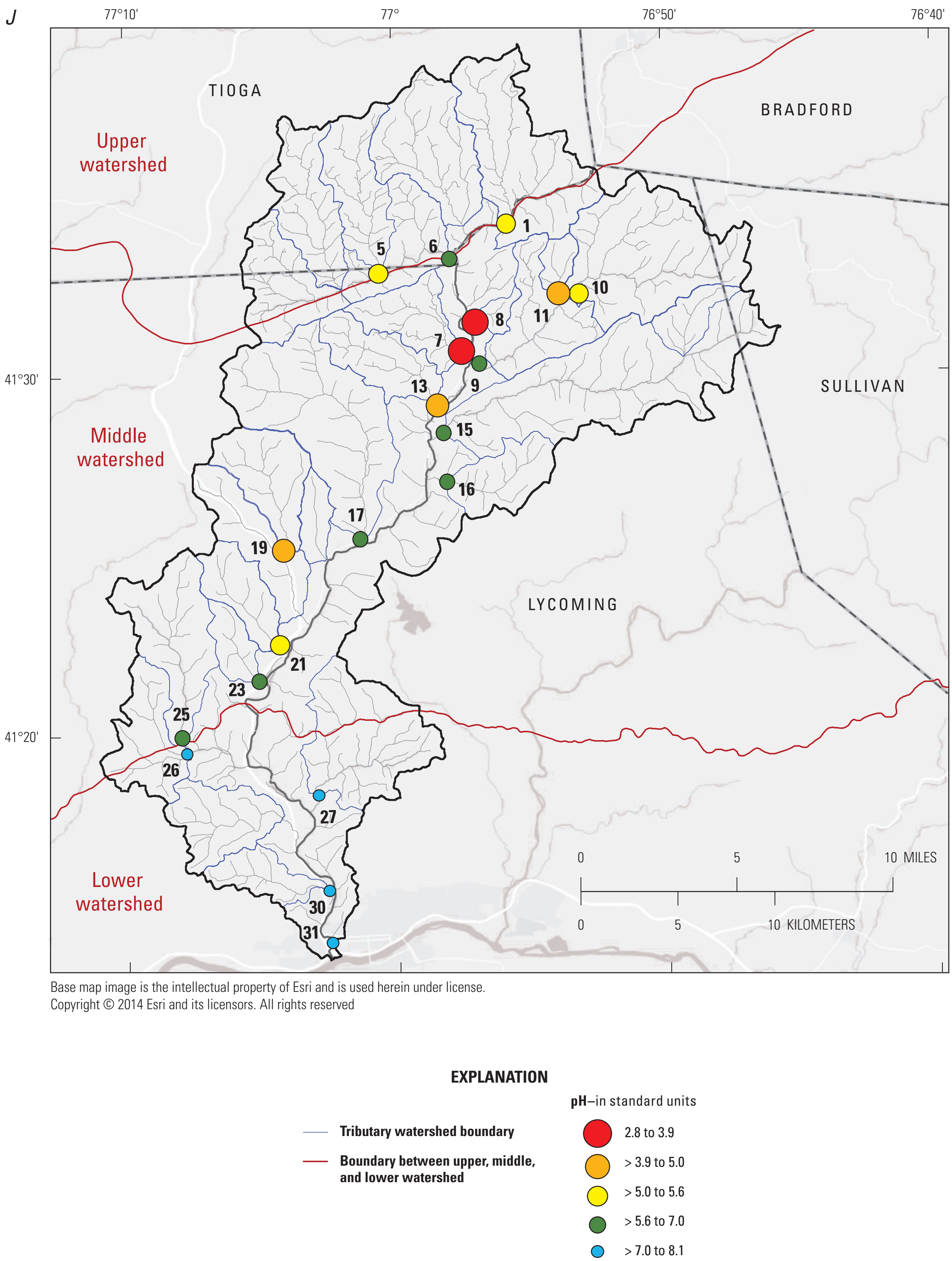


Figure 12*J*. Spatial variability for (*A*) total dissolved solids, (*B*) hardness, (*C*) acid neutralizing capacity, (*D*) chloride, (*E*) barium, (*F*) strontium, (*G*) iron, (H) zinc, (*I*) nitrate, and (*J*) field pH in the Lycoming Creek, Watershed, August 1–3, 2011. (Sites 1, 9, 24, 29, and 31 are on the main stem of Lycoming Creek)—Contuined

of hardness from 61 to 120 mg/L. Except for the sample from Dutchman Run, the moderately hard water is found in the lower part of the watershed. The highest value of 89.5 mg/L was in the sample from Bottle Run. On the main stem of Lycoming Creek the water was categorized as soft in all samples, with concentrations of hardness ranging from 38 to 45.6 mg/L.

Acid-Neutralizing Capacity

The acid neutralizing capacity (ANC) of samples ranged from 0 to 66 mg/L as calcium carbonate (fig. 12*C*). ANC refers to the capacity of solutes and particulates in an unfiltered water sample to neutralize acid (USGS, variously dated, chapter A6). For filtered samples or samples without any particulate matter, ANC is equivalent to alkalinity. The ANC was determined for all samples using either the inflection-point titration method by USGS in the field or the fixed-endpoint titration by PaDEP in the laboratory; results from the different methods are illustrated together in figure 12*C*. The ANC in stream water from the upper part of Lycoming Creek watershed was fairly similar, with values ranging from 24 to 42 mg/L. In the middle part of the watershed, some streams exhibited very low ANC. Values from four sites—Red Run (site 7), Dutchman Run (site 8), Hounds Run (site 11), and Frozen Run (site 13)—had ANC values less than or equal to 2 mg/L, and 10 other sites had concentrations less than 18 mg/L. The lowest ANC values are in samples from Dutchman Run (0 mg/L) and Red Run (0.6 mg/L), watersheds overlying coal seams that been mined in the past; the other sites with low ANC are in watersheds where the soil and rock lack the capacity to neutralize acidic precipitation. The sites with samples having the greatest ANC are in the lower part of the watershed near Williamsport, 54 mg/L in Beautys Run (site 28) and 66 mg/L in Bottle Run (site 30). Along the main stem of Lycoming Creek, the ANC was 39 mg/L near Dogtown (site 1), but decreased substantially to 15 mg/L downstream at Ralston (site 9), and then increased to 33 mg/L at 3rd Street Bridge (site 31). The changes in concentration in the main stem are caused mainly by differences in the ANC of water entering from tributary streams.

Chloride

Concentrations of chloride ranged from 0.28 to 45.4 mg/L (fig. 12*D*), but values from 24 of the 31 sites were less than 8 mg/L. The lowest concentrations were found in the middle part of the watershed, where values were less than 3 mg/L in all except three tributary streams. The notable outlier in the middle watershed is the concentration of 16.2 mg/L in Trout Run upstream of Lycoming Creek (site 20), which is most likely influenced by road salt applied to U.S. Route 15. Concentrations in the upper part of the watershed were higher than the middle watershed, ranging from about 4 to 6 mg/L, with a highest value of 11.9 mg/L in the sample from Mill Creek upstream of Roaring Branch (site 2). Four of the five highest concentrations of chloride in the Lycoming Creek watershed were from streams in the more developed lower part of the watershed. On the main stem of Lycoming Creek, concentrations of chloride in five samples ranged from 6.4 to 12.9 mg/L. Concentrations were greatest at the most downstream site on Lycoming Creek at 3rd Street Bridge (site 31) and lowest from the sample at Ralston (site 9).

Barium

Concentrations of barium ranged from 14.2 to 81.1 µg/L (fig. 12*E*), but values were less than 49 µg/L at all but 5 of 30 sites sampled. The highest barium value of 81.1 µg/L was measured in Red Run (site 7), one of the mining influenced tributaries in the middle part of Lycoming Creek watershed, but at Dutchman Run (site 8), which has also been influenced by mining, barium was only 32.3 µg/L. Except for the concentrations of 81.1 µg/L in Red Run and 49.0 µg/L in Trout Run upstream of Lycoming Creek (site 20), concentrations generally were the highest in the upper and lower parts of the Lycoming Creek watershed. On the main stem of Lycoming Creek, concentrations of barium in five samples ranged from 33 to 49.1 µg/L; the lowest value was near Heshbon Park (site 29) and the highest at the most upstream site near Dogtown (site 1).

Strontium

Concentrations of strontium ranged from 17 to 120 µg/L (fig. 12*F*). The spatial distribution of strontium values was similar to that found for barium. Samples with values greater than 60 µg/L were all from sites in the upper and lower parts of the watershed except for the sample from Trout Run upstream of Lycoming Creek (site 20). The highest concentrations of strontium were 120 µg/L in Mill Creek upstream of Roaring Branch (site 2), 105 µg/L in Bottle Run (site 30), and 80 µg/L in Beautys Run (site 28)—all streams in watersheds with large percentages of agricultural and some developed lands. On the main stem of Lycoming Creek, concentrations of strontium in five samples were fairly uniform, ranging from 50 to 74.4 µg/L. Concentrations were nearly the same (73.2 and 74.4 µg/L) at the most upstream site Lycoming Creek near Dogtown (site 1) and the most downstream site at 3rd Street Bridge (site 31).

Iron

Concentrations of iron in filtered samples ranged from less than 3.2 µg/L to 498 µg/L; however, the results were censored to different reporting levels by the USGS and PaDEP laboratories. To illustrate the spatial distribution of iron for all sites, values are censored in figure 12*G* to the largest common reporting level of 20 µg/L. Twenty-five of the thirty-one samples (81 percent) contained iron concentrations less than 20 µg/L. Except for concentrations of 498 µg/L in Dutchman Run (site 8) and 56 µg/L in Bottle Run (site 30), the values for the six other sites were less than or equal to 30 µg/L. On the main stem of Lycoming Creek, the concentrations of iron were all less than 30 µg/L, including the main stem site at Ralston (site 9) immediately downstream of the confluence with Dutchman Run.

Zinc

Concentrations of zinc in filtered samples ranged from less than 1.4 to 190 µg/L; however, the results were censored to different reporting levels by the USGS and PaDEP laboratories. To illustrate the spatial distribution of zinc for all 30 sites, values are censored in figure 12*H* to the largest common reporting level of 5 µg/L. Eighteen of the thirty samples (60 percent) contained zinc concentrations less than the common reporting level of 5 µg/L. With the exception of values for the mining-influenced sites of 190 µg/L in Dutchman Run (site 8) and 90.4 µg/L in Red Run (site 7), concentrations were all less than or equal to 20 µg/L. On the main stem of Lycoming Creek, the only concentration of zinc above the reporting level (9.9 µg/L) was from the sample at Ralston (site 9).

Nitrate

Concentrations of nitrate ranged from 0.05 to 1.55 mg/L (fig. 12*I*). Samples from only four sites, located in different parts of the watershed, had concentrations greater than 0.55 mg/L. Of those four, only the nitrate values of 1.11 mg/L from Bottle Run (site 30) and 1.55 mg/L from Mill Creek near Hepburnville (site 27) in the lower part of the watershed exceeded 1.0 mg/L. On the main stem of Lycoming Creek, nitrate values were highest (0.35 mg/L) at the most upstream site near Dogtown (site 1) and lowest (0.10 mg/L) at Haleeka (site 24).

Field pH

The pH ranged from 2.8 to 8.1 in 20 samples analyzed in the field (fig. 12*J*). The pH is 5.6 or less in samples from nine streams in the upper and middle parts of Lycoming Creek watershed. The lowest pH values of 2.8 in Dutchman Run (site 8) and 3.9 in Red Run (site 7) are influenced by weathering of sulfate minerals exposed by past coal mining in those watersheds, but the other seven streams with pH less than 5.6 are probably influenced mostly by acid deposition and lack of buffering capacity of bedrock in those watersheds. The greatest pH value of 8.1 was in the sample from Mill Creek near Hepburnville (site 27) in the lower part of the watershed. In samples from three sites on the main stem of Lycoming Creek, pH values were greatest (7.4) at the most downstream site at 3rd Street Bridge (site 31) and lowest (5.4) at the most upstream site near Dogtown (site 1).

Geology and Water Quality

The quality of surface water in the Lycoming Creek watershed is strongly influenced by the lithology of the bedrock beneath different parts of the watershed. Solutes released by weathering of minerals in the bedrock define the relative composition of major ions (water type), and provide most of the dissolved-solids concentration in the natural base flow. The lithology of the bedrock varies from the mostly fine-grained shale and siltstone in rocks of Middle Devonian age that were deposited in a marine environment, to the coarser-grained, quartz-rich sandstones and conglomerates in rocks of Late Devonian, Mississippian, and Pennsylvanian ages, that were deposited in a mostly nonmarine environment. The resistant, quartz-rich sandstones in the Huntley Mountain Formation and younger formations, exposed mostly in the middle part of Lycoming Creek watershed, are more resistant to weathering than the siltstones and shales in the Catskill Formation and older formations, which are exposed mostly in the upper and lower parts of the watershed (fig. 3).

Concentrations of 18 water-quality constituents from streams in watersheds underlain by 60 percent or more of quartz-rich sandstones (Huntley Mountain Formation and younger formations) were compared to concentrations from streams in the other watersheds underlain by more siltstone and shale (Catskill Formation and older formations) (fig. 13). Samples from streams where the water chemistry has probably been substantially affected by human activities such as mining, road deicing, and urban development were excluded (sites with map identifiers 7, 8, 20, and 30 in table 1), so the comparison would, to the extent possible, reflect differences in water quality related to bedrock lithology. Samples from the four sites on the main stem of Lycoming Creek having upstream watershed areas greater than 30 square miles also were excluded because the water quality at those sites is an integration of the upstream land uses and rock types. Figure 13*A* compares concentrations of 9 constituents from 23 sites where samples were collected by both USGS and PaDEP and concentrations in all samples were equal to or greater than the reporting limit. Figure 13*B* compares concentrations of 9 trace constituents from 15 sites where samples were collected only by USGS and less than five values were censored at the reporting level. For the purpose of this comparison, the few censored values were replaced with a concentration equal to 0.99 times the censored value for that constituent.

Figure 13 shows that concentrations for most water-quality constituents are lower in watersheds underlain predominantly by the quartz-rich sandstones (Huntley Mountain Formation and younger formations) than from watersheds underlain by siltstone and shale (Catskill Formation and older formations). Statistical analysis using the Wilcoxon rank-sum test (Helsel and Hirsch, 2002) indicates median concentrations were significantly lower in the sandstone formations ($p=0.05$) for all constituents except aluminum, lithium, and manganese, which were not significantly different. Nickel was significantly higher in watersheds underlain by sandstone. The smaller concentrations of acid-neutralizing capacity, specific conductance, total dissolved solids, hardness, and most dissolved ions in water from the quartz-rich sandstones is a result of the low solubility of quartz and intergranular cementing minerals. The higher concentrations of nickel in water of the quartz-rich sandstone group could be caused by higher nickel

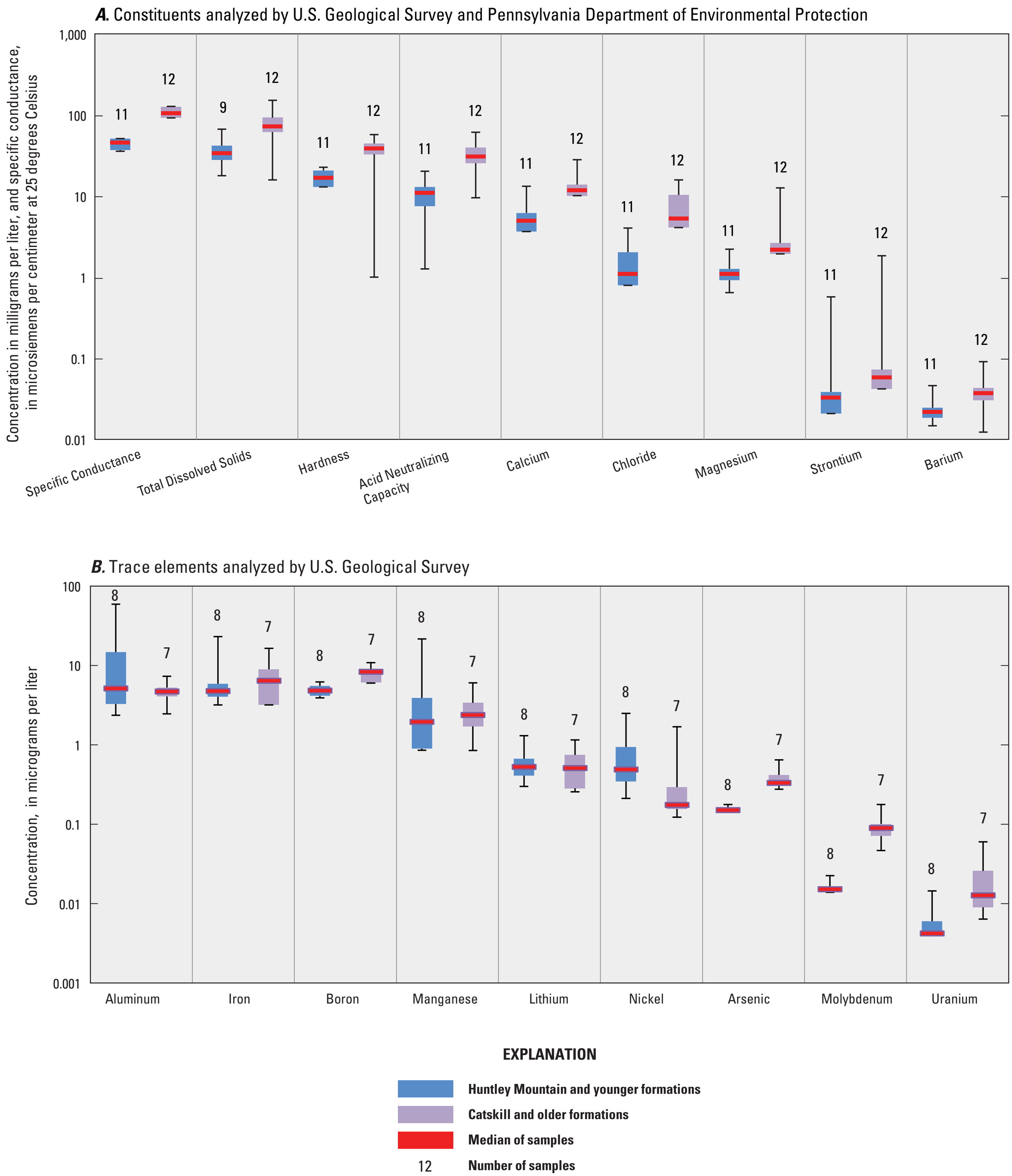


Figure 13. Comparison of concentrations for water-quality constituents from watersheds underlain predominantly by quartz sandstone (60 percent or more Huntley Mountain Formation and younger formations) and watersheds underlain by siltstone and shale (40 percent or more Catskill Formation and older formations) within the Lycoming Creek watershed, August 1–3, 2011 for (*A*) nine constituents analyzed by both the U.S. Geological Survey (USGS) and the Pennsylvania Department of Environmental Protection, and (*B*) nine trace constituents analyzed by USGS.

concentrations in coals present in the Allegheny and Pottsville Formations within that group.

The bedrock geology controls the degree to which acidic deposition affects base-flow water quality. Precipitation on the Lycoming Creek watershed is acidic, as shown by the mean pH of 4.81 from 16 precipitation samples collected in 2011 at the atmospheric-deposition monitoring station in Little Pine State Park about 9 miles west of the Lycoming Creek watershed (National Atmospheric Deposition Program, 2015). Weathering of carbonate and clay minerals from the bedrock helps to neutralize the acidity and buffer the water. Those minerals, in general, occur in greater amounts in the fine-grained shales and siltstones than in the quartz-rich sandstones. In the Lycoming Creek watershed, the ANC of surface-water samples from watersheds underlain predominantly by quartz-rich sandstones (and not substantially affected by mining) ranged from 1 to 20 and were significantly lower as a group than from watersheds underlain by more siltstone and shale, where field ANC ranged from 11 to 54 (fig. 13*A*). For streams in the middle part of the Lycoming Creek watershed that are underlain by sandstones with few carbonate or clay minerals, the ANC of stream base flow is low and acid deposition is likely a major source of the acidity (fig. 13*A*).

Land Use and Water Quality

Human activities on the landscape influence the quality of surface water in Lycoming Creek watershed. The water-quality characteristics associated with agricultural lands and developed lands are described along with the characteristics associated with historical coal mining and oil and gas development. Percentages of agricultural and developed lands in the watershed upstream from each sample site are shown in figure 10. Watersheds of tributary streams in the middle part of Lycoming Creek watershed are almost entirely forested, whereas those in the upper and lower parts of the watershed have more agriculture and developed lands.

Agriculture

Agricultural lands account for 12.5 percent of the Lycoming Creek watershed. Although every tributary watershed with the exception of Dutchman Run (site 8) contains some degree of farming activity, agriculture is found mostly in the upper and lower parts of the watershed and along the main stem of the Lycoming Creek (figs. 4 and 10). Tributary watersheds with the most agriculture as a percentage of total area are Beautys Run (site 28) with 50 percent agriculture, and Mill Creek near Hepburnville (site 27) with 46 percent agriculture, both of which are in the lower part of Lycoming Creek watershed.

Agricultural activities are sometimes associated with increased nutrients in stream base flow (Lindsey and others, 1997). Elevated levels of nitrogen and phosphorus compounds are commonplace in heavily farmed areas where fertilizers are used to increase crop outputs, and excess nutrients that are not taken up by plants can be carried to streams though sediment erosion or infiltrate into groundwater and cause elevated nutrient concentrations during base-flow periods. Of the 20 sites sampled by USGS, no samples failed to meet the MCL for nitrate of 10 mg/L as nitrogen. There were 12 samples that contained total nitrogen above 0.3 mg/L, the estimated background concentration for the region (Dubrovsky and others, 2010, p. 118). These sites are spread among tributary watersheds with differing amounts of agriculture, but the two highest values—1.8 mg/L at Mill Creek near Hepburnville (site 27) and 1.4 mg/L at Bottle Run near Williamsport (site 30)—are from watersheds with more than 35 percent agricultural lands, though inputs from other sources (such as on-lot septic and lawn fertilizers) could also contribute nutrients, especially in the Bottle Run watershed.

Total phosphorus in base flow from the 20 sites sampled by USGS was greater than the estimated natural background concentration of 0.01 mg/L (Dubrovsky and others, 2010, p. 118) at three sites. Stoney Gap Run near Quiggleville (site 26), Mill Creek near Hepburnville (site 27), and Bottle Run near Williamsport (site 30) had concentrations of 0.021, 0.041, and 0.037 mg/L, respectively; they are all in the lower watershed and have more than 25 percent of their land devoted to crops and pasture. Other sites may have had concentrations above background levels, but the reporting limit of phosphorus for NWQL was 0.02 mg/L, twice that of the estimated background concentration level.

Residential and Commercial Development

Only about 4.7 percent of the Lycoming Creek watershed is classified as developed. There is little development in the upper parts of the basin, except for areas directly adjacent to the main stem of Lycoming Creek. Development is concentrated in the lower part of the basin, accounting for just more than 15 percent of total land usage. The Bottle Run watershed contains the highest level of development (11.4 percent) of the watersheds sampled.

The development of land for residential or commercial purposes may lead to elevated levels of certain constituents in base flow, such as chloride and boron. Sources of chloride include road salt, water-conditioning salts, and waste from on-lot septic systems and various manufacturing processes. Boron is commonly elevated in septic effluent because it is an additive in some laundry detergents. Chloride ($p=0.003$) and boron ($p=0.0001$) are both found in statistically significant higher concentrations in these regions compared to the more forested areas. Bottle Run (site 30) contained elevated levels of both chloride (45.4 mg/L compared to a median of 3.8 mg/L) and boron (14.9 µg/L compared to a median of 6.1 µg/L). The three tributary watersheds with the highest boron concentrations—14.9 mg/L in Bottle Run (site 30), 10.8 mg/L in Mill Creek near Hepburnville (site 27) and 9.7 mg/L in Lycoming Creek at Third Street Bridge, Williamsport (site 31)—are all in the most developed (lower part) of the basin.

Chloride and bromide commonly are used as indicators of dilution or mixing of waters because of the conservative nature of these anions; once dissolved, they are not easily removed from solution by precipitation, ion exchange, or other reactions (Davis and others, 1998). The ratio of chloride to bromide found in fresh water is usually less than 100:1, road de-icing mixtures are about 5,000:1 to 10,000:1, and flow-back brines from oil and gas wells are about 100:1 (Whittemore, 2007). The differences in the ratios can be used to help identify the source of chloride because the mixing of different sources of water causes a change in the chloride/bromide ratio in direct proportion to the mass loading from each source. Samples from the Lycoming Creek watershed plot close to the theoretical mixing curve for freshwater and road de-icing salts (fig. 14); indicating that the source of chloride at the sample points is probably derived from de-icing salts. Infiltration of snowmelt may recharge the groundwater system with elevated levels of chloride during the winter, leading to the discharge of these salts months (or years) later in the base flow of the streams.

Mining

Bituminous coal has been extracted in the past from parts of the Lycoming Creek watershed by both surface and underground mining. The areas underlain by coal deposits, mainly in the Allegheny Formation and, to a lesser extent in the Pottsville Formation, are shown in figure 5. The presence of past surface mining is evident on topographic maps within six tributary watersheds where water samples were collected. Strip mines are shown on maps within the Dutchman Run, Red Run, and Rock Run watersheds, and in small areas along the topographic divides of Frozen Run, Hoagland Run, and Stoney Gap Run watersheds. Land usage for these areas is typically classified as barren whether or not reclamation efforts have occurred.

Water samples from Dutchman Run (site 8) and Red Run (site 7) show evidence of impacts from coal mining. The relative proportion of major ions illustrated on the Stiff diagram (fig. 11) shows that waters from Dutchman Run and Red Run are enriched in sulfate and magnesium compared to samples from other basins. Samples from Frozen Run (site 13) and Hounds Run (site 11) are also relatively enriched in sulfate, but because of the very low concentration of dissolved solids in those waters (less than 20 mg/L), it is possible that the sulfate is from atmospheric deposition and naturally weathered sulfide minerals in the rocks rather than from the impacts of coal mining. The samples from Frozen Run and Hounds Run do not contain the high dissolved solids concentration that is typical of coal-mine drainage.

The field pH values of 2.8 at Dutchman Run (site 8) and 3.9 at Red Run (site 7) were the lowest measured in the Lycoming Creek watershed. The median field pH of all watersheds sampled was 6.0, with a trend of waters becoming more neutral to slightly basic from north to south through the basin. Low pH waters can be the result of coal-mine drainage, acid deposition, and other factors. Dutchman Run and Red Run, which drain resistant Mississippian and Pennsylvanian-age sandstones, had low acid neutralizing capacities and elevated levels of several trace metals indicative of a mining history. Compared to the other tributaries, water samples from Red Run and Dutchman Run were statistically different for pH, ANC, sulfate, aluminum, beryllium, chromium, cobalt, copper, lead, lithium, manganese, nickel, selenium, and zinc (fig. 15).

The impact of coal mining is also apparent in the sample from the main stem of Lycoming Creek at Ralston (fig. 16). The sample from Lycoming Creek near Dogtown (site 1) is upstream of any coal mining; the site at Ralston (site 9) is immediately downstream of Dutchman Run and Red Run, and the site at 3rd Street Bridge (site 31) is near the mouth of Lycoming Creek. Compared to the upstream and downstream samples, the sample from Lycoming Creek at Ralston had a lower acid neutralizing capacity and higher concentrations of sulfate and other trace metals. This shows that inputs of mining-affected waters, even small amounts (but with high concentrations), can affect the concentrations of constituents in the main stem. Farther downstream in Lycoming Creek at the Third Street Bridge, ANC is higher and concentrations of sulfate and most trace metals are lower when compared to the sample at Ralston. The addition of waters from tributaries draining forested watersheds in the middle part of the basin leads to lower concentrations of many constituents at the mouth of the river.

Oil and Gas Development

Oil and gas development has the potential to affect surface-water quality from accidental spills, improper disposal of wastes, leaking wells, and land disturbance (Abdalla and others, 2011). The Pennsylvania Department of Environmental Protection (2016a) listed only six conventional vertical gas wells (all plugged) in the watershed prior to development of natural gas from the Marcellus Shale in 2007. At the time of this study on August 1, 2011, sixty-five unconventional wells had been drilled in the Lycoming Creek watershed to extract natural gas from the Marcellus Shale. About equal numbers of wells had been drilled in the upper and middle sections of the watershed and nearly all were west of the Lycoming Creek (fig. 5). The greatest density of gas wells (1.22 wells per square mile) was in Red Run watershed (table 3).

The flowback and produced waters from Marcellus gas wells contain high levels of dissolved solids in concentrations that greatly exceed levels found in natural surface waters. Hayes (2009) reported concentrations of many chemical constituents in flowback waters at 5 days after hydraulic fracturing, including total dissolved solids (38,500 to 238,000 mg/L), chloride (26,400 to 148,000 mg/L), bromide (185 to 1,190 mg/L), strontium (345 to 4,830 mg/L), and barium (21 to 13,900 mg/L), and lithium (10.6 to 153 mg/L). These constituents are some commonly cited indicators of brine contamination (Betanzo and others, 2016). Brines from Marcellus gas wells have also been reported to contain elevated levels of the radioactive element radium (Rowan and others, 2011).

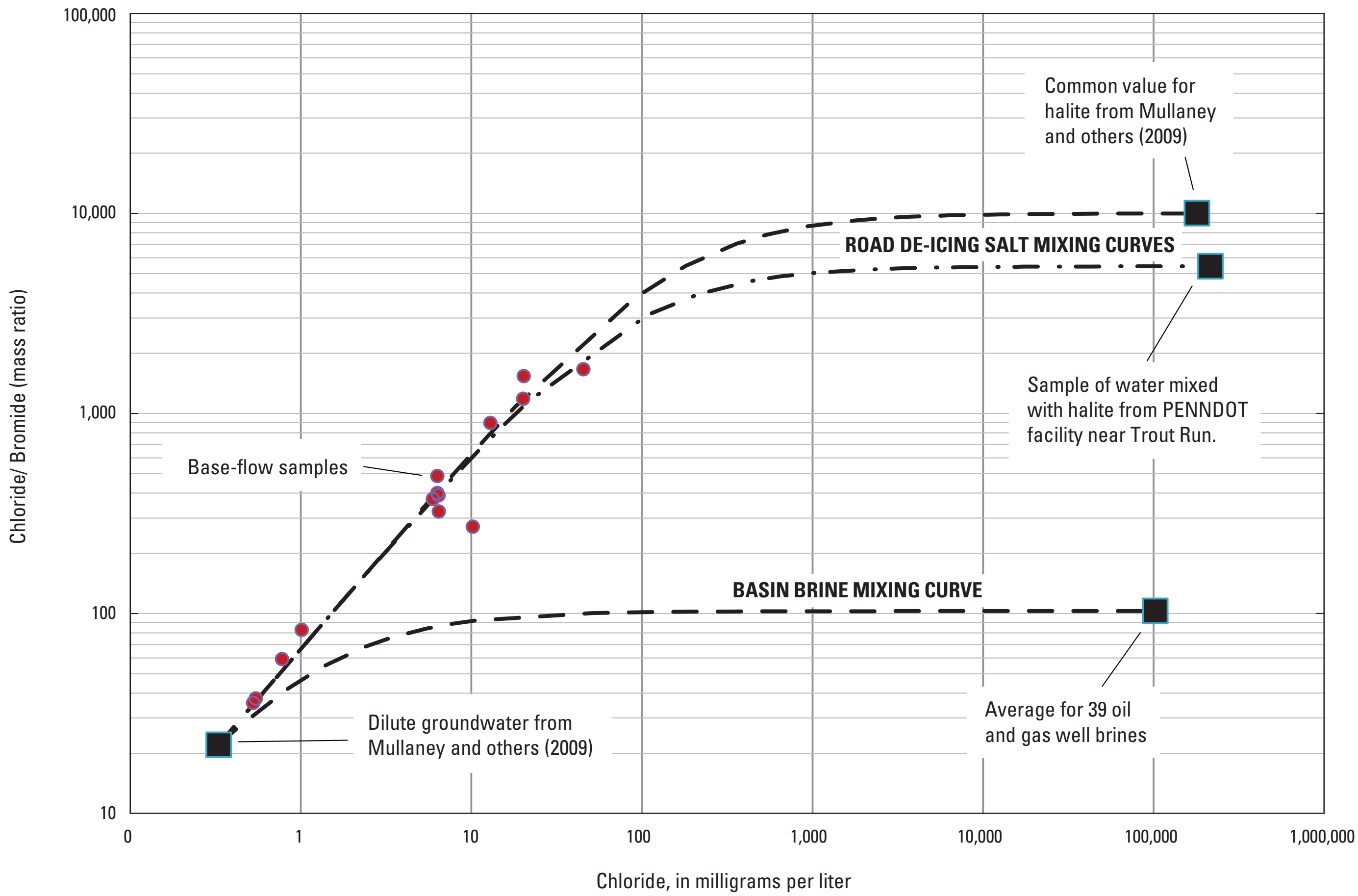


Figure 14. Relation between bromide and chloride concentrations for 14 base-flow samples from the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011 compared to theoretical mixing curves for freshwater with basin brine and road de-icing salts.

Concentrations in base-flow samples collected in the Lycoming Creek watershed ranged from <12 to 202 mg/L for total dissolved solids, 0.28 to 45.4 mg/L for chloride, <0.01 to 0.038 mg/L for bromide, 0.017 to 0.120 mg/L for strontium, 0.0142 to 0.0811 mg/L for barium, 0.00026 to 0.0492 mg/L for lithium, and <0.1 to 2.1 pCi/L for gross alpha activity. These ranges do not indicate contamination from oil-and-gas brines in any of the streams that were sampled. The calcium-bicarbonate and calcium-sulfate water types of the surface-water samples (fig. 11) did not indicate mixing with a sodium-calcium-chloride type brine from an oil and gas well (Dresel and Rose, 2010). The surface-water samples had chloride/bromide ratios more indicative of a source of chloride from road-salt than from deep basin brine (fig. 14).

Although brine releases to streams can cause degradation of stream quality, constituents that are found at high concentrations in brines may already be present during natural flow conditions. Road salt, as well as agricultural runoff and on-lot septic systems, are common sources of increased levels of chloride. Runoff and groundwater discharge from previously mined regions can contain high levels of total dissolved solids and metals such as arsenic and bromide. Fertilizers can be a source of barium and sometimes radium. A list of constituents that homeowners with private water supplies should consider having analyzed prior to any oil or gas drilling has been developed by the Pennsylvania Department of Environmental Protection (2016b).

Stream Discharge and Water Quality

This study provided a snapshot of water-quality conditions measured during a relatively stable base-flow condition of stream discharge across the Lycoming Creek watershed. The concentrations of most constituents would differ from the values reported in this study if samples were collected during periods of higher or lower flow. An example of the variability in the specific conductance is shown for samples collected at different discharges in Lycoming Creek near Trout Run, Pennsylvania (01550000) as part of the Pennsylvania Water-Quality Network (fig. 8). There is considerable scatter in the data, but also a decreasing trend in specific conductance with increasing discharge. Understanding the natural variability of constituent concentrations in surface waters will be needed to determine

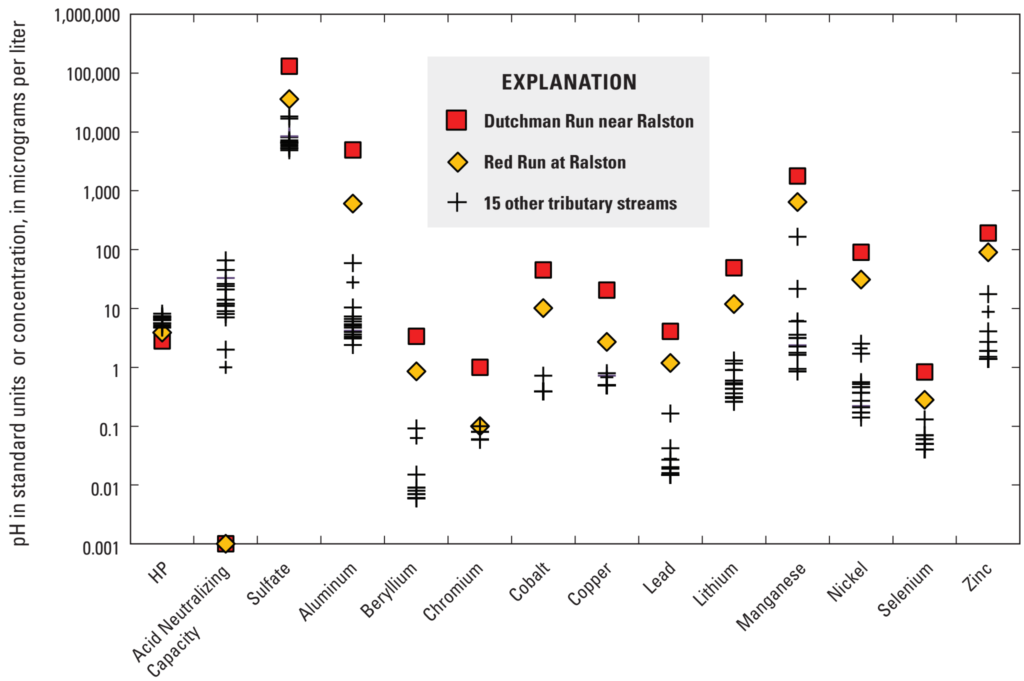


Figure 15. Constituents that were elevated in water samples from Dutchman Run near Ralston and Red Run at Ralston compared to results from samples from 15 other tributary streams in Lycoming Creek watershed, north-central Pennsylvania.

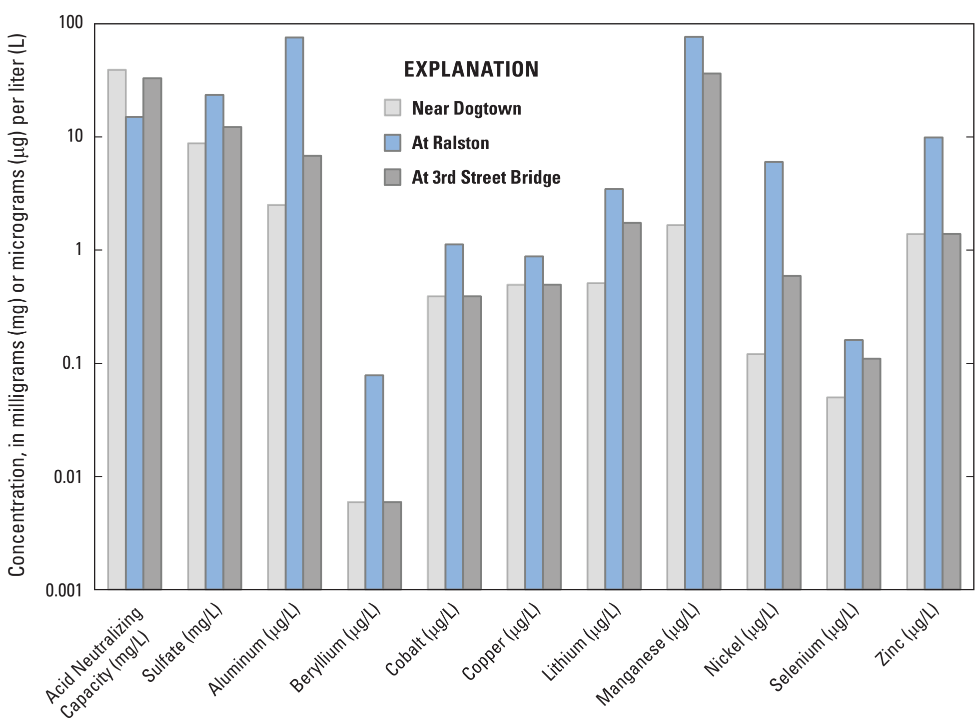


Figure 16. Comparison of selected water-quality constituents associated with coal mining at three sites on the main stem of Lycoming Creek, north-central Pennsylvania, August 1–3, 2011.

the effect of human activities on water quality; this will require the collection of multiple samples over time at various discharges. In a study designed to detect water-quality changes caused by shale-gas development or other land uses, monthly sampling is recommended for multiple years (Betanzo and others, 2016).

Summary

This report describes a survey of surface-water quality in the 272-square mile Lycoming Creek watershed within Lycoming, Tioga, and Sullivan Counties in north-central Pennsylvania. The quality of water in Lycoming Creek is of interest to the Williamsport Municipal Water Authority (WMWA) because Lycoming Creek is a source of water to their production wells, which are located near its mouth. The wells capture stream water that infiltrates through the bed of the creek, so the quality of the produced well water can be affected by changes in stream-water quality.

The study was done in cooperation with the WMWA to establish a water-quality dataset that would help document the spatial variability in constituents and provide a basis for distinguishing contaminants from land-use activities such as natural-gas development, road maintenance, agricultural operations, and urban and suburban development. The focus of this study was on the stream water quality as it relates to drinking water standards, as opposed to aquatic life.

Surface-water samples were collected by the U.S. Geological Survey (USGS) and Pennsylvania Department of Environmental Protection (PaDEP) from 31 sites in the Lycoming Creek watershed during a period of base flow August 1–3, 2011. The samples were analyzed by the USGS National Water Quality Laboratory and the PaDEP Bureau of Laboratories. Five sites were on the main stem of Lycoming Creek, and 26 sites were on tributary streams. Watershed areas upstream from the main-stem sampling sites ranged from 15.6 mi^2 for the most upstream site near Dogtown to 272 mi^2 for the most downstream site at the 3rd Street Bridge near the mouth of Lycoming Creek. The other 26 sampling sites were on 22 tributary streams—Roaring Branch, Rock Run, Trout Run, and Wolf Run were each sampled at two sites. Watersheds areas ranged from 1.1 to 30.5 mi^2 for the tributary streams that were sampled. Sampling sites on tributary streams were selected to represent watersheds with various land uses (forest, agriculture, resource extraction, development) and underlying geology.

The results of sampling show a spatial variability in water quality related to differences in land use and geology. Areas of forested lands (79 percent) are mostly in areas of rugged relief, underlain by sandstone bedrock of Mississippian and Pennsylvanian age in the middle part of the watershed; agricultural lands (15 percent) are mostly in the upper and lower parts of the watershed, underlain by siltstones and shales of Devonian age. Residential and commercial development (5 percent) is concentrated in the lower part of the watershed in the vicinity of Williamsport. Because the land use and geology are related, spatial differences in water quality are difficult to attribute to a specific rock type or land-use activity. However, except where affected by human activities, tributaries that flowed across siltstones and shales of Devonian age typically had higher concentrations of major constituents and trace metals than tributaries in watersheds underlain predominantly by the more resistant sandstone bedrock of Mississippian and Pennsylvanian age.

Water quality in tributary streams ranged from nearly pristine in forested tributaries of the middle watershed to notably influenced by human activity in areas of past coal mining and urban and suburban development. Tributary watersheds that are mostly forested with little agriculture or development typically had low concentrations of major and trace constituents and nutrients. A water sample from one such watershed, Wolf Run, had a dissolved-solids concentration of less than the laboratory reporting level of 12 mg/L. Two of the tributary streams, Dutchman Run and Red Run, contained elevated levels of several trace metals and had negligible acid neutralizing capacity, most likely due to historical coal mining activity in those areas.

Agriculture accounts for about 15 percent of land use in the Lycoming Creek watershed, and eight of the tributary watersheds in the upper and lower parts of Lycoming Creek watershed have at least 25 percent pasture and crop lands. Two tributaries with more than 35 percent of land in the watershed devoted to agriculture, Mill Creek near Hepburnville and Bottle Run, contained the highest concentrations of total nitrogen of 1.8 and 1.4 mg/L, respectively. However, overall there were no definitive relations between nutrient concentrations in water samples and percentage of land devoted to agriculture.

Developed lands account for only about 5 percent of the area of Lycoming Creek watershed, but the effects of residential and commercial development may be evident in Bottle Run, the tributary site nearest to Williamsport. The Bottle Run watershed has 11 percent of its area classified as developed, making it the most developed tributary in the Lycoming Creek watershed. The water sample from Bottle Run showed elevated levels of several constituents. It had the greatest concentrations of dissolved solids (202 mg/L), sodium (25.8 mg/L) boron (9.7 mg/L), bromide (0.027 mg/L), arsenic (0.67 mg/L), and ammonia plus organic nitrogen (0.29 mg/L) in the study. The elevated concentrations are probably related to its location in an area of residential and commercial development, along with a substantial amount of agriculture (38 percent of its area).

Overall, the quality of water in Lycoming Creek was good near the Lycoming Creek well field, where infiltration from the creek to the well field is most likely. The concentrations in the sample collected at the 3rd Street Bridge were in acceptable ranges when compared to U.S. Environmental Protection Agency's primary or secondary maximum contaminant levels, or any health-based screening levels for the constituents analyzed. Although concentrations of some metals and nutrients were greater than background levels in tributary streams affected by coal mining or development, they were diluted in the main stem of Lycoming Creek upstream from the well field.

This study examined concentrations of water-quality constituents during a relatively stable base-flow condition of stream discharge, but concentrations of most constituents would differ if samples were collected during higher or lower streamflow. Understanding the natural variability of constituent concentrations will be needed to determine the effects of human activities on water quality, which will require the collection of multiple samples over time at various discharge rates. Also, to improve the ability to determine spatial differences in water quality and trends, if multiple laboratories are used in future studies (as was the case in this study), samples should be analyzed for the same suite of chemical constituents and results reported to similar low reporting limits.

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Table 10. Results of field measurements for water-quality characteristics and analyses by the U.S. Geologcial Survey laboratory for major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek Watershed, north-central Pennsylvania, August 1–3, 2011.

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; lab, laboratory; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; PA, Pennsylvania; NTRU, Nephelometric Turbidity Ratio Unit; --, no data; <, less than; E, estimated; N, north; St, street. Standard reference sample indicated posible low bias for nitrate plus nitrite]

Station ID	Station name	Date	Sample start time	Barometric pressure, millimeters of mercury (00025)	Temperature, air, deg C (00020)	Discharge, instantaneous, cubic feet per second (00061)	Dissolved oxygen, water, unfiltered, mg/L (00300)	Dissolved oxygen, water, unfiltered, percent of saturation (00301)	pH, water, unfiltered, field, standard units (00400)	pH, water, unfiltered, laboratory, standard units (00403)
01549895	Lycoming Creek near Dogtown, PA	08/01/2011	11:00	734	24.6	0.58	7.1	74	5.4	7.2
015499015	Salt Spring Run near South Union, PA	08/02/2011	12:00	742	--	0.87	8.3	98	5.6	E7.6
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	10:30	742	23	2.2	9.5	110	6.8	8.0
01549903	Red Run at Ralston, PA	08/01/2011	13:30	737	25.3	0.51	9.9	110	3.9	4.6
015499027	Dutchman Run near Ralston, PA	08/02/2011	20:30	732	--	0.02	7.5	81	2.8	3.2
01549904	Lycoming Creek at Ralston, PA	08/01/2011	13:15	747	29.2	6.2	9.7	113	6.9	7.5
015499055	Rock Run at McIntyre Township, PA	08/02/2011	18:00	724	--	5.7	9.1	100	5.6	E7.3
015499056	Hounds Run at McIntyre Township, PA	08/02/2011	19:00	723	20	0.13	9.4	104	5.0	E6.3
01549909	Frozen Run near Ralston, PA	08/02/2011	14:30	741	33.3	0.54	9.9	113	4.9	E5.8
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	08:30	739	19	8.5	8.8	97	6.5	E7.5
01549950	Slacks Run near Bodines, PA	08/03/2011	08:30	736	20	0.93	8.7	95	7.0	E7.8
01549990	Grays Run near Fields Station, PA	08/02/2011	11:00	740	26	2.9	9.3	100	6.3	E7.4
01550100	Trout Run at Route 15N at Lewis Township, PA	08/02/2011	07:30	734	17.3	0.81	9.4	101	4.7	E7.3
01550200	Wolf Run near Trout Run, PA	08/02/2011	10:15	741	19.5	0.64	9.8	103	5.2	E7.1
01550250	Daugherty Run near Powys, PA	08/02/2011	15:45	741	22.4	0.4	8.4	92	6.5	E7.3
01550300	Hoagland Run near Quiggleville, PA	08/02/2011	09:00	740	--	2.6	8.7	94	7.0	E7.5
01550305	Stoney Gap Run near Quiggleville, PA	08/02/2011	10:45	740	28.3	1.1	9.2	100	7.3	7.7
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:00	744	31	1.8	8.8	104	8.1	8.1
01550505	Bottle Run near Williamsport, PA	08/01/2011	14:30	750	29	0.13	16	190	7.4	7.9
01550600	Lycoming Creek at 3rd St bridge, Williamsport, PA	08/01/2011	12:15	750	29	37	8.2	101	7.4	7.9

Table 10. Results of field measurements for water-quality characteristics and analyses by the U.S. Geologcial Survey laboratory for major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek Watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; lab, laboratory; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; PA, Pennsylvania; NTRU, Nephelometric Turbidity Ratio Unit; --, no data; <, less than; E, estimated; N, north; St, street. Standard reference sample indicated posible low bias for nitrate plus nitrite]

Station ID	Station name	Date	Sample start time	Specific conductance, water, unfiltered, lab, µS/cm at 25 deg C (90095)	Specific conductance, water, unfiltered, field, µS/cm at 25 deg C (00095)	Temperature, water, deg C (00010)	Turbidity, water, unfiltered, NTRU (63676)	Dissolved solids dried at 180 deg C, water, filtered, mg/L (70300)	Dissolved solids, water, filtered, sum of constituents, mg/L (70301)	Hardness, water, mg/L as calcium carbonate (00900)
01549895	Lycoming Creek near Dogtown, PA	08/01/2011	11:00	131	128	15.5	1	96	73	43.7
015499015	Salt Spring Run near South Union, PA	08/02/2011	12:00	E88.3	89	21.9	<0.1	61	49	30.8
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	10:30	108	106	21.5	0.8	79	56	38.4
01549903	Red Run at Ralston, PA	08/01/2011	13:30	103	103	18.6	1	78	58	31.3
015499027	Dutchman Run near Ralston, PA	08/02/2011	20:30	420	453	17.1	0.1	191	180	63.7
01549904	Lycoming Creek at Ralston, PA	08/01/2011	13:15	116	113	21.9	1.3	85	64	38.6
015499055	Rock Run at McIntyre Township, PA	08/02/2011	18:00	E43.8	43	17.7	0.3	28	26	15.5
015499056	Hounds Run at McIntyre Township, PA	08/02/2011	19:00	E26.8	25	17.8	0.3	14	18	7.95
01549909	Frozen Run near Ralston, PA	08/02/2011	14:30	E27.4	25	20.4	3	--	18	6.77
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	08:30	E49.4	48	18.5	1	34	27	19.8
01549950	Slacks Run near Bodines, PA	08/03/2011	08:30	E86.6	86	17.8	3.5	65	50	32.0
01549990	Grays Run near Fields Station, PA	08/02/2011	11:00	E39.6	38	17.1	0.9	32	24	14.8
01550100	Trout Run at Route 15N at Lewis Township, PA	08/02/2011	07:30	E46.7	45	17.2	2	30	29	16.8
01550200	Wolf Run near Trout Run, PA	08/02/2011	10:15	E34.2	30	16.9	1	<12	23	11.2
01550250	Daugherty Run near Powys, PA	08/02/2011	15:45	E46.7	45	18.3	1.5	28	30	17.4
01550300	Hoagland Run near Quiggleville, PA	08/02/2011	09:00	E52.9	51	17.6	5.6	38	31	21.6
01550305	Stoney Gap Run near Quiggleville, PA	08/02/2011	10:45	102	101	18.1	3	59	59	38.8
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:00	186	193	22.4	1.6	106	101	66.2
01550505	Bottle Run near Williamsport, PA	08/01/2011	14:30	326	322	23.2	8.5	202	173	89.5
01550600	Lycoming Creek at 3rd St bridge, Williamsport, PA	08/01/2011	12:15	139	129	25.1	7.2	89	72	45.6

Table 10. Results of field measurements for water-quality characteristics and analyses by the U.S. Geologcial Survey laboratory for major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek Watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; lab, laboratory; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; PA, Pennsylvania; NTRU, Nephelometric Turbidity Ratio Unit; --, no data; <, less than; E, estimated; N, north; St, street. Standard reference sample indicated posible low bias for nitrate plus nitrite]

Station ID	Station name	Date	Sample start time	Calcium, water, filtered, mg/L (00915)	Magnesium, water, filtered, mg/L (00925)	Potassium, water, filtered, mg/L (00935)	Sodium, water, filtered, mg/L (00930)	Acid neutralizing capacity, water, unfiltered, inflection-point titration method (incremental titration method), field, mg/L as calcium carbonate (00419)	Bicarbonate, water, filtered, inflection-point titration method (incremental titration method), field, mg/L (00453)
01549895	Lycoming Creek near Dogtown, PA	08/01/2011	11:00	13.8	2.22	1.27	6.61	39	47
015499015	Salt Spring Run near South Union, PA	08/02/2011	12:00	9.38	1.77	1.21	4.02	24	29
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	10:30	11.8	2.17	1.35	4.17	33	41
01549903	Red Run at Ralston, PA	08/01/2011	13:30	6.48	3.63	0.78	1.09	0.6	E4
015499027	Dutchman Run near Ralston, PA	08/02/2011	20:30	9.34	9.79	1.07	1.01	0	0
01549904	Lycoming Creek at Ralston, PA	08/01/2011	13:15	10.3	3.09	1.32	4.16	15	18
015499055	Rock Run at McIntyre Township, PA	08/02/2011	18:00	4.49	1.02	0.58	1.22	9	E11
015499056	Hounds Run at McIntyre Township, PA	08/02/2011	19:00	2.12	0.64	0.32	0.58	1	2
01549909	Frozen Run near Ralston, PA	08/02/2011	14:30	1.78	0.56	0.57	0.96	2	E2
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	08:30	6.06	1.11	0.60	0.78	12	14
01549950	Slacks Run near Bodines, PA	08/03/2011	08:30	10.2	1.59	0.78	4.13	26	31
01549990	Grays Run near Fields Station, PA	08/02/2011	11:00	4.36	0.93	0.54	0.87	8	10
01550100	Trout Run at Route 15N at Lewis Township, PA	08/02/2011	07:30	5.19	0.93	0.79	1.72	11	14
01550200	Wolf Run near Trout Run, PA	08/02/2011	10:15	2.96	0.91	0.77	0.92	7	8
01550250	Daugherty Run near Powys, PA	08/02/2011	15:45	5.08	1.14	0.98	0.94	12	14
01550300	Hoagland Run near Quiggleville, PA	08/02/2011	09:00	6.35	1.39	0.94	0.86	14	E18
01550305	Stoney Gap Run near Quiggleville, PA	08/02/2011	10:45	10.5	3.03	1.36	2.46	21	25
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:00	19.4	4.3	1.98	9.11	45	55
01550505	Bottle Run near Williamsport, PA	08/01/2011	14:30	24.6	6.79	2.24	25.8	66	80
01550600	Lycoming Creek at 3rd St bridge, Williamsport, PA	08/01/2011	12:15	14	2.56	1.24	6.66	33	40

Table 10. Results of field measurements for water-quality characteristics and analyses by the U.S. Geologcial Survey laboratory for major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek Watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; lab, laboratory; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; PA, Pennsylvania; NTRU, Nephelometric Turbidity Ratio Unit; --, no data; <, less than; E, estimated; N, north; St, street. Standard reference sample indicated posible low bias for nitrate plus nitrite]

Station ID	Station name	Date	Sample start time	Bromide, water, filtered, mg/L (71870)	Chloride, water, filtered, mg/L (00940)	Fluoride, water, filtered, mg/L (00950)	Silica, water, filtered, mg/L as SiO_2 (00955)	Sulfate, water, filtered, mg/L (00945)	Antimony, water, filtered, µg/L (01095)	Arsenic, water, filtered, µg/L (01000)	Boron, water, filtered, µg/L (01020)	Selenium, water, filtered, µg/L (01145)
01549895	Lycoming Creek near Dogtown, PA	08/01/2011	11:00	0.038	10.2	<0.04	5.15	8.77	<0.027	0.28	8.6	0.05
015499015	Salt Spring Run near South Union, PA	08/02/2011	12:00	0.016	5.94	0.07	3.70	8.12	0.043	0.33	9.2	0.04
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	10:30	0.013	6.32	0.07	1.68	8.37	0.045	0.39	8.3	0.05
01549903	Red Run at Ralston, PA	08/01/2011	13:30	0.012	1.01	0.08	5.87	36.0	0.033	0.19	6.6	0.28
015499027	Dutchman Run near Ralston, PA	08/02/2011	20:30	<0.010	0.28	0.09	20.7	130	<0.027	0.20	4.7	0.83
01549904	Lycoming Creek at Ralston, PA	08/01/2011	13:15	0.017	6.41	0.07	5.43	23.4	0.068	0.23	7.6	0.16
015499055	Rock Run at McIntyre Township, PA	08/02/2011	18:00	<0.010	2.61	0.04	4.01	5.26	<0.027	0.15	4.0	0.04
015499056	Hounds Run at McIntyre Township, PA	08/02/2011	19:00	0.015	0.525	<0.04	4.42	6.51	<0.027	0.08	4.4	0.06
01549909	Frozen Run near Ralston, PA	08/02/2011	14:30	0.013	0.78	<0.04	4.54	7.18	0.036	0.12	6.2	0.05
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	08:30	<0.010	1.1	<0.04	3.69	6.06	<0.027	0.12	5.4	0.06
01549950	Slacks Run near Bodines, PA	08/03/2011	08:30	<0.010	4.69	<0.04	4.60	6.77	0.046	0.30	6.2	0.04
01549990	Grays Run near Fields Station, PA	08/02/2011	11:00	<0.010	0.68	0.04	4.52	6.49	<0.027	0.11	3.9	0.04
01550100	Trout Run at Route 15N at Lewis Township, PA	08/02/2011	07:30	<0.010	0.85	<0.04	5.07	5.72	0.038	0.45	6.0	0.05
01550200	Wolf Run near Trout Run, PA	08/02/2011	10:15	<0.010	0.82	<0.04	5.60	5.30	<0.027	0.17	4.2	0.04
01550250	Daugherty Run near Powys, PA	08/02/2011	15:45	<0.010	0.99	<0.04	5.1	6.61	<0.027	0.15	5.2	0.05
01550300	Hoagland Run near Quiggleville, PA	08/02/2011	09:00	<0.010	1.98	<0.04	4.56	4.90	<0.027	0.18	5.9	0.05
01550305	Stoney Gap Run near Quiggleville, PA	08/02/2011	10:45	<0.010	4.66	0.04	5.31	16.8	0.045	0.32	6.0	0.07
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:00	0.013	20.3	<0.04	5.29	6.54	0.066	0.64	11	0.07
01550505	Bottle Run near Williamsport, PA	08/01/2011	14:30	0.027	45.4	0.09	5.21	18.2	0.092	0.67	15	0.13
01550600	Lycoming Creek at 3rd St bridge, Williamsport, PA	08/01/2011	12:15	0.014	12.9	0.06	1.18	12.2	0.053	0.50	9.7	0.11

Table 10. Results of field measurements for water-quality characteristics and analyses by the U.S. Geologcial Survey laboratory for major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek Watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; lab, laboratory; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; PA, Pennsylvania; NTRU, Nephelometric Turbidity Ratio Unit; --, no data; <, less than; E, estimated; N, north; St, street. Standard reference sample indicated posible low bias for nitrate plus nitrite]

Station ID	Station name	Date	Sample start time	Aluminum, water, filtered, µg/L (01106)	Barium, water, filtered, µg/L (01005)	Beryllium, water, filtered, µg/L (01010)	Cadmium, water, filtered, µg/L (01025)	Chromium, water, filtered, µg/L (01030)	Cobalt, water, filtered, µg/L (01035)	Copper, water, filtered, µg/L (01040)	Iron, water, filtered, µg/L (01046)
01549895	Lycoming Creek near Dogtown, PA	08/01/2011	11:00	2.5	41.9	<0.006	<0.016	0.065	0.03	<0.50	<3.2
015499015	Salt Spring Run near South Union, PA	08/02/2011	12:00	5.4	38.4	<0.006	<0.016	<0.06	0.05	<0.50	6.4
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	10:30	4.2	33.6	<0.006	<0.016	<0.06	0.03	0.72	<3.2
01549903	Red Run at Ralston, PA	08/01/2011	13:30	606	81.1	0.854	0.449	0.10	10.1	2.66	22.1
015499027	Dutchman Run near Ralston, PA	08/02/2011	20:30	4,950	32.3	3.38	0.452	1.00	45.1	20.5	498
01549904	Lycoming Creek at Ralston, PA	08/01/2011	13:15	75.7	38.6	0.078	0.053	0.09	1.12	0.88	3.4
015499055	Rock Run at McIntyre Township, PA	08/02/2011	18:00	6.7	16.0	0.009	<0.016	<0.06	<0.02	<0.50	<3.2
015499056	Hounds Run at McIntyre Township, PA	08/02/2011	19:00	27.8	21.9	0.063	0.105	<0.06	0.04	0.68	4.7
01549909	Frozen Run near Ralston, PA	08/02/2011	14:30	59.1	26.9	0.092	0.140	<0.06	0.1	<0.50	7.0
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	08:30	2.4	16.0	<0.006	<0.016	<0.06	<0.02	<0.50	3.2
01549950	Slacks Run near Bodines, PA	08/03/2011	08:30	4.0	29.8	<0.006	<0.016	<0.06	0.04	<0.50	<3.2
01549990	Grays Run near Fields Station, PA	08/02/2011	11:00	3.1	21.2	0.009	<0.016	<0.06	0.02	<0.50	5.5
01550100	Trout Run at Route 15N at Lewis Township, PA	08/02/2011	07:30	5.1	27.4	<0.006	<0.016	0.082	0.09	<0.50	6.6
01550200	Wolf Run near Trout Run, PA	08/02/2011	10:15	3.6	14.2	0.007	<0.016	<0.06	0.17	<0.50	4.8
01550250	Daugherty Run near Powys, PA	08/02/2011	15:45	3.3	22.0	0.007	<0.016	<0.06	<0.02	<0.50	4.3
01550300	Hoagland Run near Quiggleville, PA	08/02/2011	09:00	10.4	26.4	0.008	<0.016	<0.06	0.06	<0.50	23.1
01550305	Stoney Gap Run near Quiggleville, PA	08/02/2011	10:45	7.3	30.3	0.015	<0.016	0.08	0.11	<0.50	11.3
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:00	4.7	40.9	<0.006	<0.016	0.07	0.08	0.79	16.4
01550505	Bottle Run near Williamsport, PA	08/01/2011	14:30	6.0	26.5	<0.006	<0.016	0.10	0.72	<0.50	56.0
01550600	Lycoming Creek at 3rd St bridge, Williamsport, PA	08/01/2011	12:15	6.8	34.8	<0.006	<0.016	0.07	0.20	<0.50	24.7

Table 10. Results of field measurements for water-quality characteristics and analyses by the U.S. Geologcial Survey laboratory for major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek Watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; lab, laboratory; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; PA, Pennsylvania; NTRU, Nephelometric Turbidity Ratio Unit; --, no data; <, less than; E, estimated; N, north; St, street. Standard reference sample indicated posible low bias for nitrate plus nitrite]

Station ID	Station name	Date	Sample start time	Lead, water, filtered, µg/L (01049)	Lithium, water, filtered, µg/L (01130)	Man-ganese, water, filtered, µg/L (01056)	Molybde-num, water, filtered, µg/L (01060)	Nickel, water, filtered, µg/L (01065)	Silver, water, filtered, µg/L (01075)	Strontium, water, filtered, µg/L (01080)	Uranium (natural), water, filtered, µg/L (22703)	Zinc, water, filtered, µg/L (01090)
01549895	Lycoming Creek near Dogtown, PA	08/01/2011	11:00	0.018	0.51	1.66	0.047	0.12	<0.005	73.2	0.009	<1.4
015499015	Salt Spring Run near South Union, PA	08/02/2011	12:00	<0.015	0.90	1.76	0.065	0.17	<0.005	68.3	0.006	<1.4
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	10:30	<0.015	0.59	2.37	0.106	0.22	<0.005	56.7	0.021	<1.4
01549903	Red Run at Ralston, PA	08/01/2011	13:30	1.18	11.8	641	<0.014	30.8	<0.005	52.8	0.026	90.4
015499027	Dutchman Run near Ralston, PA	08/02/2011	20:30	4.06	49.2	1,770	<0.014	90.2	<0.005	44.9	0.688	190
01549904	Lycoming Creek at Ralston, PA	08/01/2011	13:15	0.024	3.45	76.6	0.038	6.04	<0.005	59.3	0.015	9.9
015499055	Rock Run at McIntyre Township, PA	08/02/2011	18:00	<0.015	0.54	0.94	<0.014	0.56	<0.005	37.0	<0.004	<1.4
015499056	Hounds Run at McIntyre Township, PA	08/02/2011	19:00	0.028	0.91	6.13	<0.014	2.06	<0.005	19.5	<0.004	8.8
01549909	Frozen Run near Ralston, PA	08/02/2011	14:30	0.163	1.30	21.6	<0.014	2.48	<0.005	17.0	0.015	17.4
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	08:30	<0.015	0.30	3.14	0.015	0.21	<0.005	33.1	0.004	<1.4
01549950	Slacks Run near Bodines, PA	08/03/2011	08:30	<0.015	0.26	0.61	0.095	0.18	<0.005	42.7	0.030	<1.4
01549990	Grays Run near Fields Station, PA	08/02/2011	11:00	<0.015	0.36	1.63	0.016	0.27	<0.005	21.9	0.004	1.9
01550100	Trout Run at Route 15N at Lewis Township, PA	08/02/2011	07:30	0.0163	0.26	3.58	0.077	0.14	<0.005	24.1	0.013	<1.4
01550200	Wolf Run near Trout Run, PA	08/02/2011	10:15	<0.015	0.59	0.76	0.017	0.46	<0.005	19.7	0.006	1.9
01550250	Daugherty Run near Powys, PA	08/02/2011	15:45	<0.015	0.43	0.63	0.015	0.37	<0.005	26.4	<0.004	1.5
01550300	Hoagland Run near Quiggleville, PA	08/02/2011	09:00	0.027	0.51	2.25	0.023	0.52	<0.005	32.7	0.006	2.7
01550305	Stoney Gap Run near Quiggleville, PA	08/02/2011	10:45	0.019	1.15	6.01	0.090	1.69	<0.005	51.7	0.009	4.1
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:00	0.020	0.31	3.18	0.177	0.37	<0.005	72.2	0.060	<1.4
01550505	Bottle Run near Williamsport, PA	08/01/2011	14:30	0.042	0.44	166	0.141	0.46	<0.005	105	0.055	<1.4
01550600	Lycoming Creek at 3rd St bridge, Williamsport, PA	08/01/2011	12:15	0.039	1.74	36.2	0.162	0.59	<0.005	74.4	0.017	<1.4

Table 10. Results of field measurements for water-quality characteristics and analyses by the U.S. Geologcial Survey laboratory for major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek Watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; lab, laboratory; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; PA, Pennsylvania; NTRU, Nephelometric Turbidity Ratio Unit; --, no data; <, less than; E, estimated; N, north; St, street. Standard reference sample indicated posible low bias for nitrate plus nitrite]

Station ID	Station name	Date	Sample start time	Ammonia plus organic nitrogen, water, unfiltered, mg/L as nitrogen (00625)	Ammonia, water, filtered, mg/L as nitrogen (00608)	Nitrate plus nitrite, water, filtered, mg/L as nitrogen (00631)	Nitrate, water, filtered, mg/L as nitrogen (00618)	Nitrite, water, filtered, mg/L as nitrogen (00613)
01549895	Lycoming Creek near Dogtown, PA	08/01/2011	11:00	0.06	<0.01	0.35	0.347	<0.001
015499015	Salt Spring Run near South Union, PA	08/02/2011	12:00	0.11	0.06	0.15	0.15	<0.001
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	10:30	0.11	<0.01	0.05	0.052	<0.001
01549903	Red Run at Ralston, PA	08/01/2011	13:30	0.06	<0.01	0.21	0.206	0.001
015499027	Dutchman Run near Ralston, PA	08/02/2011	20:30	<0.05	<0.01	0.06	0.057	<0.001
01549904	Lycoming Creek at Ralston, PA	08/01/2011	13:15	0.06	<0.01	0.18	0.179	0.001
015499055	Rock Run at McIntyre Township, PA	08/02/2011	18:00	<0.05	<0.01	0.38	0.377	<0.001
015499056	Hounds Run at McIntyre Township, PA	08/02/2011	19:00	<0.05	<0.01	0.33	0.331	<0.001
01549909	Frozen Run near Ralston, PA	08/02/2011	14:30	0.08	<0.01	0.20	0.196	<0.001
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	08:30	0.06	<0.01	0.23	0.226	0.001
01549950	Slacks Run near Bodines, PA	08/03/2011	08:30	0.07	<0.01	0.38	0.377	<0.001
01549990	Grays Run near Fields Station, PA	08/02/2011	11:00	0.05	<0.01	0.16	0.161	<0.001
01550100	Trout Run at Route 15N at Lewis Township, PA	08/02/2011	07:30	0.08	<0.01	0.45	0.454	<0.001
01550200	Wolf Run near Trout Run, PA	08/02/2011	10:15	0.06	<0.01	0.39	0.392	<0.001
01550250	Daugherty Run near Powys, PA	08/02/2011	15:45	0.06	<0.01	0.56	0.555	0.001
01550300	Hoagland Run near Quiggleville, PA	08/02/2011	09:00	0.09	<0.01	0.21	0.211	<0.001
01550305	Stoney Gap Run near Quiggleville, PA	08/02/2011	10:45	0.10	<0.01	0.41	0.406	<0.001
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:00	0.20	<0.01	1.56	1.55	0.003
01550505	Bottle Run near Williamsport, PA	08/01/2011	14:30	0.29	0.04	1.12	1.11	0.009
01550600	Lycoming Creek at 3rd St bridge, Williamsport, PA	08/01/2011	12:15	0.18	0.01	0.18	0.172	0.004

Table 10. Results of field measurements for water-quality characteristics and analyses by the U.S. Geologcial Survey laboratory for major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek Watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; lab, laboratory; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; PA, Pennsylvania; NTRU, Nephelometric Turbidity Ratio Unit; --, no data; <, less than; E, estimated; N, north; St, street. Standard reference sample indicated posible low bias for nitrate plus nitrite]

Station ID	Station name	Date	Sample start time	Organic nitrogen, water, unfiltered, mg/L as nitrogen (00605)	Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, unfiltered, mg/L (00600)	Orthophos-phate, water, filtered, mg/L as phosphorus (00671)	Phosphorus, water, filtered, mg/L as phosphorus (00666)	Phosphorus, water, unfiltered, mg/L as phosphorus (00665)
01549895	Lycoming Creek near Dogtown, PA	08/01/2011	11:00	<0.06	0.41	0.008	<0.02	<0.02
015499015	Salt Spring Run near South Union, PA	08/02/2011	12:00	0.05	0.26	0.006	<0.02	<0.02
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	10:30	<0.11	0.16	<0.004	<0.02	<0.02
01549903	Red Run at Ralston, PA	08/01/2011	13:30	<0.06	0.27	<0.004	<0.02	<0.02
015499027	Dutchman Run near Ralston, PA	08/02/2011	20:30	<0.05	<0.11	0.005	<0.02	<0.02
01549904	Lycoming Creek at Ralston, PA	08/01/2011	13:15	<0.06	0.24	<0.004	<0.02	<0.02
015499055	Rock Run at McIntyre Township, PA	08/02/2011	18:00	<0.05	<0.43	<0.004	<0.02	<0.02
015499056	Hounds Run at McIntyre Township, PA	08/02/2011	19:00	<0.05	<0.38	<0.004	<0.02	<0.02
01549909	Frozen Run near Ralston, PA	08/02/2011	14:30	<0.07	0.27	<0.004	<0.02	<0.02
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	08:30	<0.06	0.28	<0.004	<0.02	<0.02
01549950	Slacks Run near Bodines, PA	08/03/2011	08:30	<0.07	0.45	0.012	<0.02	<0.02
01549990	Grays Run near Fields Station, PA	08/02/2011	11:00	<0.05	0.21	<0.004	<0.02	<0.02
01550100	Trout Run at Route 15N at Lewis Township, PA	08/02/2011	07:30	<0.08	0.54	0.021	0.02	<0.02
01550200	Wolf Run near Trout Run, PA	08/02/2011	10:15	<0.06	0.45	0.007	<0.02	<0.02
01550250	Daugherty Run near Powys, PA	08/02/2011	15:45	<0.06	0.62	0.010	<0.02	<0.02
01550300	Hoagland Run near Quiggleville, PA	08/02/2011	09:00	<0.09	0.3	<0.004	<0.02	<0.02
01550305	Stoney Gap Run near Quiggleville, PA	08/02/2011	10:45	<0.10	0.51	0.015	<0.02	0.021
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:00	<0.20	1.8	0.032	0.04	0.041
01550505	Bottle Run near Williamsport, PA	08/01/2011	14:30	0.25	1.4	0.011	<0.02	0.037
01550600	Lycoming Creek at 3rd St bridge, Williamsport, PA	08/01/2011	12:15	0.17	0.36	<0.004	<0.02	<0.02

Table 11. Detailed radiochemical analytical results for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.

[Result, radiological concentration; CSU, combined standard uncertainty (1-sigma); ssLc, sample-specific critical level; 72-h, sample analyzed for concentration at approximately 72 hours after sample collection as referenced to a detector calibrated using ^{230}Th for gross alpha and ^{137}Cs for gross beta; 30-d, sample used for the 72-hour analysis is counted a second time approximately 30 days after the initial count as referenced to a detector calibrated using ^{230}Th for gross alpha and ^{137}Cs for gross beta; pCi/L; picocuries per liter; PA, Pennsylvania; St, street; N, north]

Station ID	Station name	Sample collection date and time	Radiological constituent	Result (pCi/L)	CSU (pCi/L)	ssLc (pCi/L)
01549895	Lycoming Creek near Dogtown, PA	8/1/11 11:00	Gross alpha (72-h)	R0.0	0.22	0.34
			Gross alpha (30-d)	R0.2	0.23	0.31
			Gross beta (72-h)	1.3	0.27	0.39
			Gross beta (30-d)	1.2	0.46	0.7
015499001	Roaring Branch near Roaring Branch, PA	8/1/11 10:30	Gross alpha (72-h)	0.5	0.22	0.27
			Gross alpha (30-d)	R-0.2	0.25	0.43
			Gross beta (72-h)	1.2	0.29	0.42
			Gross beta (30-d)	1.8	0.42	0.59
01549903	Red Run at Ralston, PA	8/1/11 13:30	Gross alpha (72-h)	2.1	0.39	0.27
			Gross alpha (30-d)	1.2	0.38	0.37
			Gross beta (72-h)	0.7	0.37	0.58
			Gross beta (30-d)	1.5	0.44	0.64
01549909	Frozen Run near Ralston, PA	8/2/11 14:30	Gross alpha (72-h)	0.35	0.17	0.21
			Gross alpha (30-d)	R0.2	0.23	0.32
			Gross beta (72-h)	0.5	0.28	0.43
			Gross beta (30-d)	0.8	0.39	0.6
01549990	Grays Run near Fields Station, PA	8/2/11 11:00	Gross alpha (72-h)	R0.2	0.28	0.39
			Gross alpha (30-d)	R0.0	0.2	0.31
			Gross beta (72-h)	R-0.1	0.7	1.1
			Gross beta (30-d)	R0.5	0.41	0.68
01550100	Trout Run at Route 15N at Lewis Township, PA	8/2/11 7:30	Gross alpha (72-h)	R0.35	0.33	0.46
			Gross alpha (30-d)	R0.0	0.23	0.35
			Gross beta (72-h)	1.1	0.45	0.68
			Gross beta (30-d)	0.8	0.38	0.58
01550200	Wolf Run near Trout Run, PA	8/2/11 10:15	Gross alpha (72-h)	R0.1	0.28	0.41
			Gross alpha (30-d)	R-0.1	0.23	0.36
			Gross beta (72-h)	R-0.3	0.5	0.86
			Gross beta (30-d)	R0.7	0.48	0.78

Table 11. Detailed radiochemical analytical results for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Result, radiological concentration; CSU, combined standard uncertainty (1-sigma); ssLc, sample-specific critical level; 72-h, sample analyzed for concentration at approximately 72 hours after sample collection as referenced to a detector calibrated using ^{230}Th for gross alpha and ^{137}Cs for gross beta; 30-d, sample used for the 72-hour analysis is counted a second time approximately 30 days after the initial count as referenced to a detector calibrated using ^{230}Th for gross alpha and ^{137}Cs for gross beta; pCi/L; picocuries per liter; PA, Pennsylvania; St, street; N, north]

Station ID	Station name	Sample collection date and time	Radiological constituent	Result (pCi/L)	CSU (pCi/L)	ssLc (pCi/L)
01550250	Daugherty Run near Powys, PA	8/2/11 15:00	Gross alpha (72-h)	R0.1	0.23	0.33
			Gross alpha (30-d)	R0.18	0.18	0.22
			Gross beta (72-h)	R0.5	0.55	0.87
			Gross beta (30-d)	R1.3	0.47	0.71
01550300	Hogeland Run near Quiggleville, PA	8/2/11 9:00	Gross alpha (72-h)	R0.16	0.17	0.24
			Gross alpha (30-d)	0.4	0.26	0.33
			Gross beta (72-h)	R0.4	0.37	0.58
			Gross beta (30-d)	1.1	0.42	0.64
01550305	Stoney Gap Run near Quiggleville, PA	8/2/11 10:45	Gross alpha (72-h)	R0.23	0.18	0.24
			Gross alpha (30-d)	R0.2	0.23	0.3
			Gross beta (72-h)	0.9	0.27	0.4
			Gross beta (30-d)	1.5	0.56	0.81
01550600	Lycoming Creek at 3rd St Bridge, Williamsport, PA	8/1/11 12:15	Gross alpha (72-h)	R-0.08	0.19	0.32
			Gross alpha (30-d)	R0.1	0.21	0.29
			Gross beta (72-h)	R-0.4	0.48	0.8
			Gross beta (30-d)	R-0.0	0.38	0.61

Table 12. Results of analyses of quality-assurance samples by the U.S. Geological Survey laboratory for major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; Blank, inorganic blank sample; Std ref, standard reference sample; Grab, noncomposite grab sample; --, no data; <, less than; E, estimated; PA, Pennsylvania]

Station number	Station name	Date	Sample start time	Sample Type	pH, water, unfiltered, laboratory, standard units (00403)	Specific conductance, water, unfiltered, lab, µS/cm at 25 deg C (90095)	Dissolved solids dried at 180 deg C, water, filtered, mg/L (70300)	Hardness, water, mg/L as calcium carbonate (00900)	Calcium, water, filtered, mg/L (00915)	Magnesium, water, filtered, mg/L (00925)	Potassium, water, filtered, mg/L (00935)
01550505	Bottle Run near Williamsport, PA	8/1/2011	1500	Blank	E6.4	<5	<12	<0.09	<0.022	<0.008	<0.022
01549950	Slacks Run near Bodines, PA	8/1/2011	1500	Std Ref	--	--	--	47.6	13.6	3.26	1.51
015499027	Dutchman Run near Ralston, PA	8/2/2011	2031	Rep	3.2	420	182	63.7	9.37	9.78	1.09
015499056	Hounds Run at McIntyre Township, PA	8/2/2011	1901	Rep	E6.2	E27.3	17	8.03	2.15	0.635	0.347
015499001	Roaring Branch near Roaring Branch, PA	8/1/2011	1045	Grab	8.1	108	65	37.8	11.6	2.14	1.42
01549904	Lycoming Creek at Ralston, PA	8/1/2011	1330	Grab	7.5	116	81	37.7	10.1	3.02	1.3
01549930	Pleasant Stream at Marsh Hill, PA	8/2/2011	900	Grab	E7.5	E49.0	36	19.8	6.05	1.12	0.644
01549990	Grays Run near Fields Station, PA	8/2/2011	1130	Grab	E7.3	E39.5	28	14.7	4.32	0.926	0.542
01550350	Mill Creek near Hepburnville, PA	8/2/2011	1330	Grab	8.1	186	102	66.2	19.4	4.3	2.04

Table 12. Results of analyses of quality-assurance samples by the U.S. Geological Survey laboratory for major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; Blank, inorganic blank sample; Std ref, standard reference sample; Grab, noncomposite grab sample; --, no data; <, less than; E, estimated; PA, Pennsylvania]

Station number	Station name	Date	Sample start time	Sample Type	Sodium, water, filtered, mg/L (00930)	Bromide, water, filtered, mg/L (71870)	Chloride, water, filtered, mg/L (00940)	Fluoride, water, filtered, mg/L (00950)	Silica, water, filtered, mg/L as SiO_2 (00955)	Sulfate, water, filtered, mg/L (00945)	Antimony, water, filtered, µg/L (01095)
01550505	Bottle Run near Williamsport, PA	8/1/2011	1500	Blank	<0.06	<0.010	<0.06	<0.04	<0.029	<0.09	<0.027
01549950	Slacks Run near Bodines, PA	8/1/2011	1500	Std Ref	15.2	--	--	--	14.2	--	3.26
015499027	Dutchman Run near Ralston, PA	8/2/2011	2031	Rep	1.02	<0.010	0.30	0.08	20.5	131	<0.027
015499056	Hounds Run at McIntyre Township, PA	8/2/2011	1901	Rep	0.592	0.015	0.54	<0.04	4.39	6.87	<0.027
015499001	Roaring Branch near Roaring Branch, PA	8/1/2011	1045	Grab	4.19	0.016	6.32	0.06	1.78	8.26	0.043
01549904	Lycoming Creek at Ralston, PA	8/1/2011	1330	Grab	4.15	0.020	6.44	0.06	5.46	23.5	0.070
01549930	Pleasant Stream at Marsh Hill, PA	8/2/2011	900	Grab	0.819	<0.010	1.02	<0.04	3.69	6.15	<0.027
01549990	Grays Run near Fields Station, PA	8/2/2011	1130	Grab	0.832	<0.010	0.68	<0.04	4.54	6.62	<0.027
01550350	Mill Creek near Hepburnville, PA	8/2/2011	1330	Grab	9.1	0.017	20.1	<0.04	5.21	7	0.059

Table 12. Results of analyses of quality-assurance samples by the U.S. Geological Survey laboratory for major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; Blank, inorganic blank sample; Std ref, standard reference sample; Grab, noncomposite grab sample; --, no data; <, less than; E, estimated; PA, Pennsylvania]

Station number	Station name	Date	Sample start time	Sample Type	Arsenic, water, filtered, µg/L (01000)	Boron, water, filtered, µg/L (01020)	Selenium, water, filtered, µg/L (01145)	Aluminum, water, filtered, µg/L (01106)	Barium, water, filtered, µg/L (01005)	Beryllium, water, filtered, µg/L (01010)	Cadmium, water, filtered, µg/L (01025)
01550505	Bottle Run near Williamsport, PA	8/1/2011	1500	Blank	0.025	<3.0	<0.03	<1.7	<0.07	<0.006	<0.016
01549950	Slacks Run near Bodines, PA	8/1/2011	1500	Std Ref	6.56	16	1.3	16.6	24.2	4.07	1.68
015499027	Dutchman Run near Ralston, PA	8/2/2011	2031	Rep	0.232	5.3	0.80	4,810	31.9	3.77	0.463
015499056	Hounds Run at McIntyre Township, PA	8/2/2011	1901	Rep	0.074	4.4	0.05	21.2	21.9	0.063	0.101
015499001	Roaring Branch near Roaring Branch, PA	8/1/2011	1045	Grab	0.376	8.4	0.05	6.25	32.2	<0.006	<0.016
01549904	Lycoming Creek at Ralston, PA	8/1/2011	1330	Grab	0.173	7.6	0.15	39.4	37.6	0.047	0.045
01549930	Pleasant Stream at Marsh Hill, PA	8/2/2011	900	Grab	0.127	5.2	0.06	2.8	15.7	0.006	<0.016
01549990	Grays Run near Fields Station, PA	8/2/2011	1130	Grab	0.109	4.0	0.05	4.4	21.2	0.009	<0.016
01550350	Mill Creek near Hepburnville, PA	8/2/2011	1330	Grab	0.6	10.6	0.07	4.1	40.7	<0.006	0.016

Table 12. Results of analyses of quality-assurance samples by the U.S. Geological Survey laboratory for major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; Blank, inorganic blank sample; Std ref, standard reference sample; Grab, noncomposite grab sample; --, no data; <, less than; E, estimated; PA, Pennsylvania]

Station number	Station name	Date	Sample start time	Sample Type	Chromium, water, filtered, µg/L (01030)	Cobalt, water, filtered, µg/L (01035)	Copper, water, filtered, µg/L (01040)	Iron, water, filtered, µg/L (01046)	Lead, water, filtered, µg/L (01049)	Lithium, water, filtered, µg/L (01130)	Manganese, water, filtered, µg/L (01056)
01550505	Bottle Run near Williamsport, PA	8/1/2011	1500	Blank	<0.06	0.08	<0.5	<3.2	<0.015	<0.05	0.17
01549950	Slacks Run near Bodines, PA	8/1/2011	1500	Std Ref	5.49	5.38	7.49	68.9	9.2	9.75	12.2
015499027	Dutchman Run near Ralston, PA	8/2/2011	2031	Rep	0.99	45.2	20.4	495	4.09	47.6	1,780
015499056	Hounds Run at McIntyre Township, PA	8/2/2011	1901	Rep	<0.06	0.02	<0.5	<3.2	0.016	0.91	6.09
015499001	Roaring Branch near Roaring Branch, PA	8/1/2011	1045	Grab	<0.06	0.03	0.72	3.5	0.045	0.61	2.46
01549904	Lycoming Creek at Ralston, PA	8/1/2011	1330	Grab	<0.06	1.12	0.69	<3.2	<0.015	3.46	71.7
01549930	Pleasant Stream at Marsh Hill, PA	8/2/2011	900	Grab	<0.06	<0.02	<0.5	<3.2	<0.015	0.29	3.23
01549990	Grays Run near Fields Station, PA	8/2/2011	1130	Grab	<0.06	<0.02	<0.5	5.9	<0.015	0.35	1.55
01550350	Mill Creek near Hepburnville, PA	8/2/2011	1330	Grab	<0.06	0.06	0.63	16	0.016	0.31	3.23

Table 12. Results of analyses of quality-assurance samples by the U.S. Geological Survey laboratory for major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; Blank, inorganic blank sample; Std ref, standard reference sample; Grab, noncomposite grab sample; --, no data; <, less than; E, estimated; PA, Pennsylvania]

Station number	Station name	Date	Sample start time	Sample Type	Molybdenum, water, filtered, µg/L (01060)	Nickel, water, filtered, µg/L (01065)	Silver, water, filtered, µg/L (01075)	Strontium, water, filtered, µg/L (01080)	Zinc, water, filtered, µg/L (01090)	Uranium (natural), water, filtered, µg/L (22703)	Ammonia plus organic nitrogen, water, unfiltered, mg/L as nitrogen (00625)	Ammonia, water, filtered, mg/L as nitrogen (00608)
01550505	Bottle Run near Williamsport, PA	8/1/2011	1500	Blank	<0.014	<0.09	<0.005	<0.2	<1.4	<0.004	<0.05	<0.01
01549950	Slacks Run near Bodines, PA	8/1/2011	1500	Std Ref	4.62	4.78	4.26	84.6	10.8	1.84	--	0.19
015499027	Dutchman Run near Ralston, PA	8/2/2011	2031	Rep	<0.014	90	<0.005	43.7	189	0.688	0.147	0.02
015499056	Hounds Run at McIntyre Township, PA	8/2/2011	1901	Rep	<0.014	2.05	<0.005	19.7	8.8	<0.004	<0.05	<0.01
015499001	Roaring Branch near Roaring Branch, PA	8/1/2011	1045	Grab	0.111	0.228	<0.005	56.6	<1.4	0.024	0.11	<0.01
01549904	Lycoming Creek at Ralston, PA	8/1/2011	1330	Grab	0.032	5.72	<0.005	58.8	8.44	0.004	0.06	<0.01
01549930	Pleasant Stream at Marsh Hill, PA	8/2/2011	900	Grab	0.016	0.22	<0.005	32.6	<1.4	0.004	<0.05	<0.01
01549990	Grays Run near Fields Station, PA	8/2/2011	1130	Grab	<0.014	0.27	<0.005	22.1	1.78	0.005	<0.05	<0.01
01550350	Mill Creek near Hepburnville, PA	8/2/2011	1330	Grab	0.163	0.34	<0.005	71.3	<1.4	0.061	0.21	<0.01

Table 12. Results of analyses of quality-assurance samples by the U.S. Geological Survey laboratory for major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; Blank, inorganic blank sample; Std ref, standard reference sample; Grab, noncomposite grab sample; --, no data; <, less than; E, estimated; PA, Pennsylvania]

Station number	Station name	Date	Sample start time	Sample Type	Nitrate plus nitrite, water, filtered, mg/L as nitrogen (00631)	Nitrate, water, filtered, mg/L as nitrogen (00618)	Nitrite, water, filtered, mg/L as nitrogen (00613)	Organic nitrogen, water, unfiltered, mg/L as nitrogen (00605)	Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, unfiltered, mg/L (00600)	Ortho-phosphate, water, filtered, mg/L as phosphorus (00671)	Phosphorus, water, filtered, mg/L as phosphorus (00666)	Phosphorus, water, unfiltered, mg/L as phosphorus (00665)
01550505	Bottle Run near Williamsport, PA	8/1/2011	1500	Blank	<0.02	<0.02	<0.001	<0.05	<0.07	<0.004	<0.02	<0.02
01549950	Slacks Run near Bodines, PA	8/1/2011	1500	Std Ref	0.21	0.21	0.001	--	--	0.2	0.277	--
015499027	Dutchman Run near Ralston, PA	8/2/2011	2031	Rep	0.06	0.06	<0.001	0.13	0.21	0.004	<0.02	<0.02
015499056	Hounds Run at McIntyre Township, PA	8/2/2011	1901	Rep	0.33	0.33	<0.001	<0.05	<0.38	<0.004	<0.02	<0.02
015499001	Roaring Branch near Roaring Branch, PA	8/1/2011	1045	Grab	0.05	0.05	<0.001	<0.11	0.16	0.005	<0.02	<0.02
01549904	Lycoming Creek at Ralston, PA	8/1/2011	1330	Grab	0.17	0.17	0.001	<0.06	0.23	<0.004	<0.02	<0.02
01549930	Pleasant Stream at Marsh Hill, PA	8/2/2011	900	Grab	0.23	0.23	<0.001	<0.05	<0.28	<0.004	<0.02	<0.02
01549990	Grays Run near Fields Station, PA	8/2/2011	1130	Grab	0.15	0.15	<0.001	<0.05	<0.20	<0.004	<0.02	<0.02
01550350	Mill Creek near Hepburnville, PA	8/2/2011	1330	Grab	1.55	1.55	0.003	<0.21	1.8	0.034	0.04	0.04

Table 13. Results of analyses by the Pennsylvania Department of Environmental Protection laboratory for water-quality characteristics, major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; lab, laboratory; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data; <, less than; PA, Pennsylvania]

Station ID	Station name	Date	Sample start time	pH, water, unfiltered, laboratory, standard units (00403)	Specific conductance, water, unfiltered, laboratory, µS/cm at 25 deg C (90095)	Dissolved solids dried at 180 deg C, water, filtered, mg/L (70300)	Hardness, water, unfiltered, calculated, mg/L as calcium carbonate (00907)	Suspended solids, water, unfiltered, mg/L (00530)	Calcium, water, unfiltered, mg/L as calcium carbonate (00910)	Magnesium, water, unfiltered, recoverable, mg/L (00927)	Acid neutralizing capacity, water, unfiltered, fixed endpoint (pH 4.5) titration, laboratory, mg/L as calcium carbonate (00417)
Environmental samples–Equal width interval composite samples											
01549898	Mill Creek upstream of Roaring Branch, PA	08/03/2011	08:05	7.3	126	74	39	<5	12	2.2	29
015499012	Roaring Branch US of Brion Cr nr South Union, PA	08/03/2011	07:30	7.4	117	72	46	<5	14	2.5	42
015499011	Brion Creek near South Union, PA	08/03/2011	07:30	7.3	94	62	33	<5	10	2.0	28
015499068	Rock Run upstream of Lycoming Creek nr Ralston, PA	08/03/2011	08:20	7	46	42	17	<5	5	1.1	11
01549920	North Pleasant Stream at Masten, PA	08/03/2011	09:00	7.2	76	44	28	<5	8.2	1.8	20
01550010	Hagerman Run near Trout Run, PA	08/03/2011	09:50	7.4	103	92	44	<5	13	2.5	39
01550150	Trout Run upstream of Lycoming Creek at Trout Run,PA	08/03/2011	10:10	7.6	158	104	51	<5	16	2.3	36
01550205	Wolf Run upstream of Lycoming Creek nr Trout Run, PA	08/03/2011	10:15	6.8	59	44	22	<5	6.4	1.4	18
01550260	Lycoming Creek at Haleeka, PA	08/03/2011	10:35	7.6	110	90	38	<5	12	1.9	29
01550380	Beautys Run near Hepburnville, PA	08/02/2011	13:45	7.5	170	102	61	<5	17	4.4	54
01550390	Lycoming Creek near Heshbon Park, PA	08/02/2011	14:00	7.6	120	66	42	<5	13	2.2	31
Quality-assurance–Equal width interval composite samples											
01549904	Lycoming Creek at Ralston, PA	08/01/2011	13:15	7.4	115	78	40	<5	11	3	17

Table 13. Results of analyses by the Pennsylvania Department of Environmental Protection laboratory for water-quality characteristics, major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; lab, laboratory; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data; <, less than; PA, Pennsylvania]

Station ID	Station name	Date	Sample start time	pH, water, unfiltered, laboratory, standard units (00403)	Specific conductance, water, unfiltered, laboratory, µS/cm at 25 deg C (90095)	Dissolved solids dried at 180 deg C, water, filtered, mg/L (70300)	Hardness, water, unfiltered, calculated, mg/L as calcium carbonate (00907)	Suspended solids, water, unfiltered, mg/L (00530)	Calcium, water, unfiltered, mg/L as calcium carbonate (00910)	Magnesium, water, unfiltered, recoverable, mg/L (00927)	Acid neutralizing capacity, water, unfiltered, fixed endpoint (pH 4.5) titration, laboratory, mg/L as calcium carbonate (00417)
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	08:30	7.1	52	40	20	<5	6	1.1	14
01549990	Grays Run near Fields Station, PA	08/02/2011	11:00	7.0	41	30	14	<5	4.2	0.9	9
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:00	7.9	198	126	68	<5	20	4.2	51
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	10:30	7.9	107	74	39	<5	12	2.1	34
Quality-assurance–Grab samples in stream thalweg											
01549904	Lycoming Creek at Ralston, PA	08/01/2011	14:00	7.4	116	78	40	<5	11	3	17
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	09:01	7.1	52	30	19	<5	5.8	1.1	13
01549990	Grays Run near Fields Station, PA	08/02/2011	11:31	6.9	41	34	14	<5	4.3	0.9	8
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:31	7.9	196	136	68	<5	20	4.2	50
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	11:45	8.3	108	70	37	<5	12	1.9	33

Table 13. Results of analyses by the Pennsylvania Department of Environmental Protection laboratory for water-quality characteristics, major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; lab, laboratory; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data; <, less than; PA, Pennsylvania]

Station ID	Station name	Date	Sample start time	Acidity, water, unfiltered, mg/L as calcium carbonate (00435)	Bromide, water, unfil-tered, mg/L (63689)	Chloride, water, unfil-tered, mg/L (99220)	Sulfate, water, unfil-tered, mg/L (00946)	Aluminum, water, filtered, µg/L (01106)	Aluminum, water, unfil-tered, recover-able, µg/L (01105)	Barium, water, unfil-tered, recover-able, µg/L (01007)	Cadmium, water, filtered, µg/L (01025)	Cadmium, water, unfiltered, µg/L (01027)
Environmental samples–Equal width interval composite samples												
01549898	Mill Creek upstream of Roaring Branch, PA	08/03/2011	08:05	-20	<0.2	12	<15.0	<200	<10.0	61	<0.2	<0.2
015499012	Roaring Branch US of Brion Cr nr South Union, PA	08/03/2011	07:30	-36	<0.2	3.8	<15.0	<200	<10.0	51	<0.2	<0.2
015499011	Brion Creek near South Union, PA	08/03/2011	07:30	-18	<0.2	4.2	<15.0	<200	<10.0	36	<0.2	<0.2
015499068	Rock Run upstream of Lycoming Creek nr Ralston, PA	08/03/2011	08:20	-4.8	<0.2	2.1	<15.0	<200	<10.0	21	<0.2	<0.2
01549920	North Pleasant Stream at Masten, PA	08/03/2011	09:00	-12	<0.2	3.0	<15.0	<200	10.6	29	<0.2	<0.2
01550010	Hagerman Run near Trout Run, PA	08/03/2011	09:50	-30	<0.2	1.2	<15.0	<200	23.9	30	<0.2	<0.2
01550150	Trout Run upstream of Lycoming Creek at Trout Run,PA	08/03/2011	10:10	-27	<0.2	16	<15.0	<200	<10.0	49	<0.2	<0.2
01550205	Wolf Run upstream of Lycoming Creek nr Trout Run, PA	08/03/2011	10:15	-9	<0.2	1.8	<15.0	<200	22.3	23	<0.2	<0.2
01550260	Lycoming Creek at Haleeka, PA	08/03/2011	10:35	-19	<0.2	6.9	<15.0	<200	17.3	35	<0.2	<0.2
01550380	Beautys Run near Hepburnville, PA	08/02/2011	13:45	-45	<0.2	11	<15.0	<200	140	47	<0.2	<0.2
01550390	Lycoming Creek near Heshbon Park, PA	08/02/2011	14:00	-26	<0.2	7.9	<15.0	<200	37.8	33	<0.2	<0.2
Quality-assurance–Equal width interval composite samples												
01549904	Lycoming Creek at Ralston, PA	08/01/2011	13:15	-9.8	<0.2	5.3	21	<200	180	40	<0.2	<0.2
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	08:30	-8.6	<0.2	1.3	<15.0	<200	<10	27	<0.2	<0.2
01549990	Grays Run near Fields Station, PA	08/02/2011	11:00	-3.2	<0.2	1	<15.0	<200	<10	22	<0.2	<0.2

Table 13. Results of analyses by the Pennsylvania Department of Environmental Protection laboratory for water-quality characteristics, major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

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Station ID	Station name	Date	Sample start time	Acidity, water, unfiltered, mg/L as calcium carbonate (00435)	Bromide, water, unfiltered, mg/L (63689)	Chloride, water, unfiltered, mg/L (99220)	Sulfate, water, unfiltered, mg/L (00946)	Aluminum, water, filtered, µg/L (01106)	Aluminum, water, unfiltered, recoverable, µg/L (01105)	Barium, water, unfiltered, recoverable, µg/L (01007)	Cadmium, water, filtered, µg/L (01025)	Cadmium, water, unfiltered, µg/L (01027)
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:00	-45	<0.2	19	<15.0	<200	24.7	43	<0.2	<0.2
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	10:30	-24	<0.2	5.5	<15.0	<200	12	34	<0.2	<0.2
Quality-assurance–Grab samples in stream thalweg												
01549904	Lycoming Creek at Ralston, PA	08/01/2011	14:00	-6.4	<0.2	5.8	23.2	<200	200	41	<0.2	<0.2
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	09:01	-7.8	<0.2	1.2	<15.0	<200	<10	17	<0.2	<0.2
01549990	Grays Run near Fields Station, PA	08/02/2011	11:31	-3.4	<0.2	1.1	<15.0	<200	<10	24	<0.2	<0.2
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:31	-41	<0.20	19	<15.0	<200	72.9	45	<0.2	<0.2
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	11:45	-22	<0.2	5.7	<15.0	<200	13	34	<0.2	<0.2

Table 13. Results of analyses by the Pennsylvania Department of Environmental Protection laboratory for water-quality characteristics, major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

[Value in parentheses is the parameter code, a 5-digit number used in the U.S. Geological Survey computerized data system to uniquely identify a specific constituent; lab, laboratory; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data; <, less than; PA, Pennsylvania]

Station ID	Station name	Date	Sample start time	Chromium, water, unfiltered, recoverable, µg/L (01034)	Copper, water, filtered, µg/L (01040)	Copper, water, unfiltered, recoverable, µg/L (01042)	Iron, water, filtered, µg/L (01046)	Iron, water, unfiltered, recoverable, µg/L (01045)	Lead, water, filtered, µg/L (01049)	Lead, water, unfiltered, recoverable, µg/L (01051)	Manganese, water, unfiltered, recoverable, µg/L (01055)	Nickel, water, filtered, µg/L (01065)
Environmental samples–Equal width interval composite samples												
01549898	Mill Creek upstream of Roaring Branch, PA	08/03/2011	08:05	<50	<4	<4	<20	20	<1	<1	<10	<4
015499012	Roaring Branch US of Brion Cr nr South Union, PA	08/03/2011	07:30	<50	<4	<4	<20	20	<1	<1	20	<4
015499011	Brion Creek near South Union, PA	08/03/2011	07:30	<50	<4	<4	<20	<20	<1	<1	<10	<4
015499068	Rock Run upstream of Lycoming Creek nr Ralston, PA	08/03/2011	08:20	<50	<4	<4	<20	<20	<1	<1	<10	<4
01549920	North Pleasant Stream at Masten, PA	08/03/2011	09:00	<50	<4	<4	<20	<20	<1	<1	<10	<4
01550010	Hagerman Run near Trout Run, PA	08/03/2011	09:50	<50	<4	<4	<20	30	<1	<1	<10	<4
01550150	Trout Run upstream of Lycoming Creek at Trout Run,PA	08/03/2011	10:10	<50	<4	<4	<20	<20	<1	<1	<10	<4
01550205	Wolf Run upstream of Lycoming Creek nr Trout Run, PA	08/03/2011	10:15	<50	<4	<4	<20	230	<1	<1	30	<4
01550260	Lycoming Creek at Haleeka, PA	08/03/2011	10:35	<50	<4	<4	<20	30	<1	<1	30	<4
01550380	Beautys Run near Hepburnville, PA	08/02/2011	13:45	<50	<4	<4	<20	400	<1	<1	100	<4
01550390	Lycoming Creek near Heshbon Park, PA	08/02/2011	14:00	<50	<4	<4	30	80	<1	<1	30	<4
Quality-assurance–Equal width interval composite samples												
01549904	Lycoming Creek at Ralston, PA	08/01/2011	13:15	<50	<4	<4	<20	30	<1	<1	90	6.1
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	08:30	<50	<4	<4	<20	<20	<1	<1	<10	<4
01549990	Grays Run near Fields Station, PA	08/02/2011	11:00	<50	<4	<4	<30	40	<1	<1	<10	<4

Table 13. Results of analyses by the Pennsylvania Department of Environmental Protection laboratory for water-quality characteristics, major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

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Station ID	Station name	Date	Sample start time	Chromium, water, unfiltered, recoverable, µg/L (01034)	Copper, water, filtered, µg/L (01040)	Copper, water, unfiltered, recoverable, µg/L (01042)	Iron, water, filtered, µg/L (01046)	Iron, water, unfiltered, recoverable, µg/L (01045)	Lead, water, filtered, µg/L (01049)	Lead, water, unfiltered, recoverable, µg/L (01051)	Manganese, water, unfiltered, recoverable, µg/L (01055)	Nickel, water, filtered, µg/L (01065)
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:00	<50	<4	<4	<20	60	<1	<1	<10	<4
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	10:30	<50	<4	<4	<20	20	<1	<1	<10	<4
Quality-assurance–Grab samples in stream thalweg												
01549904	Lycoming Creek at Ralston, PA	08/01/2011	14:00	<50	<4	<4	<20	30	<1	<1	90	6.1
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	09:01	<50	<4	<4	<20	20	<1	<1	<10	<4
01549990	Grays Run near Fields Station, PA	08/02/2011	11:31	<50	<4	<4	20	60	<1	<1	<10	<4
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:31	<50	<4	<4	<20	160	<1	<1	20	<4
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	11:45	<50	<4	20	<20	<20	<1	<1	<10	<4

Table 13. Results of analyses by the Pennsylvania Department of Environmental Protection laboratory for water-quality characteristics, major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

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Station ID	Station name	Date	Sample start time	Nickel, water, unfiltered, recoverable, mg/L (01067)	Strontium, water, unfiltered, recoverable, µg/L (01082)	Zinc, water, filtered, µg/L (01090)	Zinc, water, unfiltered, recoverable, µg/L (01092)	Arsenic, water, filtered, µg/L (01000)	Arsenic, water, unfiltered, µg/L (01002)	Ammonia, water, unfiltered, mg/L as nitrogen (00610)	Nitrate, water, unfiltered, mg/L as nitrogen (00620)	Nitrite, water, unfiltered, mg/L as nitrogen (00615)	Phosphorus, water, unfiltered, mg/L as phosphorus (00665)
Environmental samples–Equal width interval composite samples													
01549898	Mill Creek upstream of Roaring Branch, PA	08/03/2011	08:05	<4	120	6.9	5.6	<3.0	<3	<0.02	0.68	<0.01	0.01
015499012	Roaring Branch US of Brion Cr nr South Union, PA	08/03/2011	07:30	<4	40	<5	<5	<3.0	<3	<0.02	0.21	<0.01	0.01
015499011	Brion Creek near South Union, PA	08/03/2011	07:30	<4	40	<5	5.1	<3.0	<3	<0.02	0.18	<0.01	<0.01
015499068	Rock Run upstream of Lycoming Creek nr Ralston, PA	08/03/2011	08:20	<4	40	7.4	7.3	<3.0	<3	<0.02	0.38	<0.01	<0.01
01549920	North Pleasant Stream at Masten, PA	08/03/2011	09:00	<4	60	5.6	8.2	<3.0	<3	<0.02	0.95	<0.01	<0.01
01550010	Hagerman Run near Trout Run, PA	08/03/2011	09:50	<4	60	5	7.2	<3.0	<3	<0.02	0.32	<0.01	0.01
01550150	Trout Run upstream of Lycoming Creek at Trout Run,PA	08/03/2011	10:10	<4	70	6.7	20	<3.0	<3	<0.02	0.47	<0.01	<0.01
01550205	Wolf Run upstream of Lycoming Creek nr Trout Run, PA	08/03/2011	10:15	<4	40	7.5	10	<3.0	<3	<0.02	0.28	<0.01	0.01
01550260	Lycoming Creek at Haleeka, PA	08/03/2011	10:35	<4	50	--	--	--	--	<0.02	0.10	<0.01	<0.01
01550380	Beautys Run near Hepburnville, PA	08/02/2011	13:45	<4	80	6.6	7.7	<3.0	<3	<0.02	0.11	<0.01	0.03
01550390	Lycoming Creek near Heshbon Park, PA	08/02/2011	14:00	<4	60	<5	5.7	<3.0	<3	<0.02	0.18	<0.01	<0.01
Quality-assurance–Equal width interval composite samples													
01549904	Lycoming Creek at Ralston, PA	08/01/2011	13:15	6.6	60	10	10	<3.0	<3	<0.02	0.16	<0.010	<0.01
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	08:30	<4	30	6.0	6.7	<3.0	<3	<0.02	0.21	<0.010	<0.01
01549990	Grays Run near Fields Station, PA	08/02/2011	11:00	<4	20	6.5	9.2	<3.0	<3	<0.02	0.13	<0.010	<0.01

Table 13. Results of analyses by the Pennsylvania Department of Environmental Protection laboratory for water-quality characteristics, major ions, trace constituents, and nutrients for water samples collected from streams in the Lycoming Creek watershed, north-central Pennsylvania, August 1–3, 2011.—Continued

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Station ID	Station name	Date	Sample start time	Nickel, water, unfil-tered, recover-able, mg/L (01067)	Strontium, water, unfil-tered, recover-able, µg/L (01082)	Zinc, water, filtered, µg/L (01090)	Zinc, water, unfil-tered, recover-able, µg/L (01092)	Arsenic, water, filtered, µg/L (01000)	Arsenic, water, unfil-tered, µg/L (01002)	Ammonia, water, unfil-tered, mg/L as nitrogen (00610)	Nitrate, water, unfil-tered, mg/L as nitrogen (00620)	Nitrite, water, unfil-tered, mg/L as nitrogen (00615)	Phospho-rus, water, unfil-tered, mg/L as phosphorus (00665)
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:00	<4	70	7.2	6.9	<3.0	<3	<0.02	1.52	<0.010	0.02
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	10:30	<4	50	<5	<5	<3.0	<3	<0.02	<0.04	<0.010	0.01
	Quality-assurance–Grab samples in stream thalweg												
01549904	Lycoming Creek at Ralston, PA	08/01/2011	14:00	6.6	60	10	10	<3.0	<3	<0.02	0.15	<0.010	0.01
01549930	Pleasant Stream at Marsh Hill, PA	08/02/2011	09:01	<4	30	<5	<5	<3.0	<3	<0.02	0.20	<0.010	<0.01
01549990	Grays Run near Fields Station, PA	08/02/2011	11:31	<4	20	6.0	6.7	<3.0	<3	<0.02	0.13	<0.010	<0.01
01550350	Mill Creek near Hepburnville, PA	08/02/2011	13:31	<4	70	5.9	5.3	<3.0	<3	0.21	1.50	<0.010	0.02
015499001	Roaring Branch near Roaring Branch, PA	08/01/2011	11:45	<4	50	7	8	<3.0	<3	<0.02	<0.04	<0.010	0.01

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