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In cooperation with the Allegheny County Sanitary Authority and the Allegheny County Health Department

Fecal-Indicator Bacteria in the Allegheny, Monongahela, and Ohio Rivers and Selected Tributaries, Allegheny County, Pennsylvania, 2001–2005

Scientific Investigations Report 2006–5216

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

Cover. View of confluence of the Allegheny and Monongahela Rivers forming the Ohio River at Pittsburgh, Pennsylvania. (Photograph by Michael J. Langland, U.S. Geological Survey).

Table 5. Summary statistics for streamflow, temperature, turbidity, and concentrations of fecal-indicator bacteria for the eight sampling sites on Chartiers Creek, Sawmill Run, Thompson Run, and Turtle Creek, Allegheny County, Pennsylvania, 2004–2005.—Continued

[n, number of samples; WQS, 30-day geometric mean water-quality standards or criteria; NTU, Nephelometric Turbidity Units; n/a, not applicable; <, less than]

Sample statistics	Streamflow, in cubic feet per second	Temperature, in degrees Celsius	Turbidity, in NTU	Fecal coliform, in colonies per 100 milliliters[1]	*Escherichia coli*, in colonies per 100 milliliters[2]	Enterococci, in colonies per 100 milliliters[2]
Chartiers Creek near Bridgeville						
Minimum	37.0	3.9	1.4	110	100	10
Median	250	17.0	34	2,150	1,750	1,200
Maximum	13,500	22.5	340	32,000	28,000	23,000
n	34	33	32	34	34	34
Percentage of samples exceeding WQS	n/a	n/a	n/a	85	74	91
Chartiers Creek at Carnegie						
Minimum	64.0	4.0	11	<10	<10	40
Median	390	15.9	70	2,600	2,200	1,200
Maximum	11,600	23.14	1,900	110,000	150,000	40,000
n	97	96	80	97	97	97
Percentage of samples exceeding WQS	n/a	n/a	n/a	91	84	78

[1]May 1 to September 30 water-quality standard is 200 colonies per 100 milliliters for fecal coliform (Pennsylvania Code, 25 PaCode § 93.7).

[2]Year round water-quality criteria is 235 and 61 colonies per 100 milliliters for *Escherichia coli* and enterococci, respectively (U.S. Environmental Protection Agency, 1986).

Table 6. Summary of Spearman's rho correlations between fecal-indicator bacteria concentrations in water and field characteristics at the (A) Three Rivers sites and (B) select tributary sites near Pittsburgh, Pennsylvania, 2001–2005.—Continued

[n, number of samples; rho, Spearman's rho; p-value, probability; <, less than; bold type indicates statistically significant correlation at the 95-percent confidence level (p-value 0.05 or less)]

(B) Tributary sites

Variable	n	Fecal coliform		*Escherichia coli*		Enterococci	
		rho	p-value	rho	p-value	rho	p-value
Turtle Creek at Trafford							
Streamflow	21	0.202	0.380	0.308	0.175	0.138	0.565
Water temperature	23	.081	.714	-.062	.778	.210	.358
pH	23	-.149	.499	-.152	.488	-.033	.881
Specific conductance	23	-.411	.052	-.456	**.029**	-.331	.123
Dissolved oxygen	23	-.552	**.006**	-.483	**.020**	-.501	**.015**
Turbidity	23	.547	**.007**	.602	**.002**	.526	**.010**
Thompson Run at Gascola							
Streamflow	21	.192	.404	.290	.202	.158	.494
Water temperature	23	.179	.415	.068	.758	.222	.309
pH	22	.195	.384	.217	.331	.090	.691
Specific conductance	23	-.677	**.0004**	-.761	**<.0001**	-.645	**.0009**
Dissolved oxygen	23	-.223	.306	-.280	.441	-.193	.377
Turbidity	24	.188	.378	.272	.199	.203	.341
Thompson Run at Turtle Creek							
Streamflow	22	.190	.397	.397	.067	.025	.912
Water temperature	23	.043	.844	.031	.889	.203	.352
pH	23	.314	.145	.219	.314	.442	**.035**
Specific conductance	23	-.586	**.003**	-.750	**<.0001**	-.579	**.004**
Dissolved oxygen	23	-.219	.314	-.102	.642	-.324	.132
Turbidity	25	.352	.084	.456	**.022**	.287	.164
Turtle Creek at East Pittsburgh							
Streamflow	17	.333	.191	.465	.060	.568	**.017**
Water temperature	23	-.390	.066	-.318	.140	-.374	.079
pH	23	.034	.876	.070	.753	-.034	.877
Specific conductance	23	-.431	**.040**	-.514	**.012**	-.759	**<.0001**
Dissolved oxygen	23	-.264	.223	-.166	.450	-.216	.321
Turbidity	25	.562	**.0004**	.529	**.006**	.545	**.005**
Sawmill Run at Castle Shannon							
Streamflow	27	.628	**.0004**	.613	**.0007**	.303	.124
Water temperature	33	-.021	.907	-.080	.658	.139	.440
pH	32	-.503	**.003**	-.593	**.0003**	-.323	.071
Specific conductance	32	-.281	.119	-.240	.185	-.436	**.013**
Dissolved oxygen	33	-.240	.178	-.282	.112	-.325	.065
Turbidity	32	.594	**.0003**	.547	**.001**	.544	**.001**

Comparisons were made between fecal-indicator bacteria and turbidity data from right-bank and composite samples, left-bank and composite samples, and right-bank and left-bank samples collected during dry- and wet-weather conditions at the upstream and downstream Three Rivers sampling locations within each of the three subbasins.

Differences in the bacteriological quality of waters among Three Rivers sites were observed by comparing composite samples collected during dry- and wet-weather conditions. As would be expected, samples collected during high flow and turbid water conditions following storms contained higher bacteria concentrations than samples collected during dry-weather conditions. In particular, two major storms—those resulting from remnants of Hurricanes Frances and Ivan in September 2004—produced some of the highest measurements of select field characteristics and fecal-indicator bacteria. The range in bacteria concentrations grouped by Three Rivers sites during dry weather, wet weather day one, and wet weather day three are shown in figure 2. The range in bacteria concentrations grouped by tributary site during dry weather, wet weather day one, and wet weather day two are shown in figure 3.

Overall, about 35 percent of the composite samples collected at the Three Rivers sites had bacteria concentrations that exceeded recreational water-quality standards or criteria during dry- or wet-weather events. Median bacteria concentrations generally were higher in the wet-weather day-one composite samples compared to the dry-weather or wet-weather day-three composite samples at the Three Rivers sites (fig. 2); many median wet-weather day-one concentrations were higher than the water-quality standards or criteria. For example, all wet-weather day-one concentrations observed for fecal coliform, *E. coli*, and enterococci in composite samples collected at Allegheny River at 9th Street Bridge, Monongahela River at Pittsburgh, and Ohio River at Sewickley exceeded standards and criteria. The median bacteria concentrations were highest in the wet-weather day-one composite samples collected at Monongahela River at Pittsburgh; median concentrations for fecal coliform, *E. coli*, and enterococci were 1,340, 1,130, and 130 col/100 mL, respectively. Median bacteria concentrations in the dry-weather samples were below recreational water-quality standards and criteria for all fecal-indicator bacteria analyzed. Median bacteria concentrations in the wet-weather day-three composite samples tended to fall below the water-quality standards and criteria, in many cases near or below the median bacteria concentrations in the dry-weather composite samples. During dry- and wet-weather conditions, composite samples collected at Allegheny River at Oakmont and Monongahela River at McKeesport (Three Rivers sites furthest upstream) generally had lower bacteria concentrations than composite samples collected at Allegheny River at 9th Street Bridge, Monongahela River at Pittsburgh, or Ohio River at Sewickley.

Fecal-indicator bacteria concentrations in the dry- and wet-weather composite samples collected at the tributary sites (fig. 3) were more frequently above water-quality standards or criteria than composite samples collected at the Three Rivers sites. Many of the median bacteria concentrations in the dry-weather composite samples and wet-weather composite samples collected at the tributaries were above bacteria standards and criteria. Median bacteria concentrations in the wet-weather day-one composite samples collected at the tributaries generally were higher than median bacteria concentrations in the dry-weather or wet-weather day-two composite samples. Fecal coliform and *E. coli* bacteria concentrations in the wet-weather composite samples were highest in the samples collected at Sawmill Run at Duquesne Heights; median concentrations in the wet-weather day-one composite samples were around 100,000 col/100 mL. All wet-weather day-one bacteria concentrations from composite samples collected at the tributary sites exceeded recreational water-quality standards and criteria, with the exception of Thompson Run at Gascola that had concentrations from about half of the composite samples exceeding the standards and criteria. Median bacteria concentrations generally were higher during dry- and wet-weather conditions in the sites furthest downstream—Turtle Creek at East Pittsburgh and Sawmill Run and Chartiers Creek tributaries. The tributary site with the lowest median bacteria concentrations and the fewest cases of water-quality standards and criteria being exceeded during both dry- and wet-weather conditions was Thompson Run at Gascola. The upstream tributary sites on Turtle Creek, Thompson Run, and Chartiers Creek were the only sites with at least one median bacteria concentration in a dry-weather sample below water-quality standards or criteria.

The effects of extreme wet-weather conditions on streamflow and fecal-indicator bacteria concentrations also were evaluated by comparing samples collected at tributary sites before and after a major storm. On September 8, 2004, heavy rains that were the remnants of Hurricane Frances fell on western Pennsylvania. The long-term rain gage at Pittsburgh International Airport recorded 3.60 in. Rainfall totals were as high as 5.0 in. in parts of north-central and western areas of Allegheny County. The southeastern areas of Allegheny County, the area of Chartiers Creek in Washington County, and the part of Turtle Creek in Westmoreland County received in the range of 2-3 in. of rain.

Streamflow on tributary streams increased quickly on September 8, 2004, as a result of the rainfall and runoff during the day (table 7). The timing and magnitude of the highest mean daily streamflow varied from site to site as a function of precipitation amounts, runoff characteristics, and drainage-basin size upstream of the streamflow-gaging station. The highest mean daily streamflow was on September 8, 2004 (wet-weather day one), for Thompson Run at Turtle Creek and Sawmill Run at Duquesne Heights. These streams with drainage areas of 18.0 and 18.1 mi^2, respectively (table 1), are small urban watersheds with considerable amounts of impervious surfaces and steep stream gradients. The storm hydrographs showed rapid rises and rapid recessions from the storm runoff. Turtle Creek at Wilmerding, with a drainage area of 123 mi^2, and Chartiers Creek at Carnegie, with a drainage area of 257 mi^2, had the highest mean daily streamflow of the wet-weather event on September 9, 2004 (wet-weather day two). Stormwater runoff in the larger drainage area watersheds of Turtle Creek and

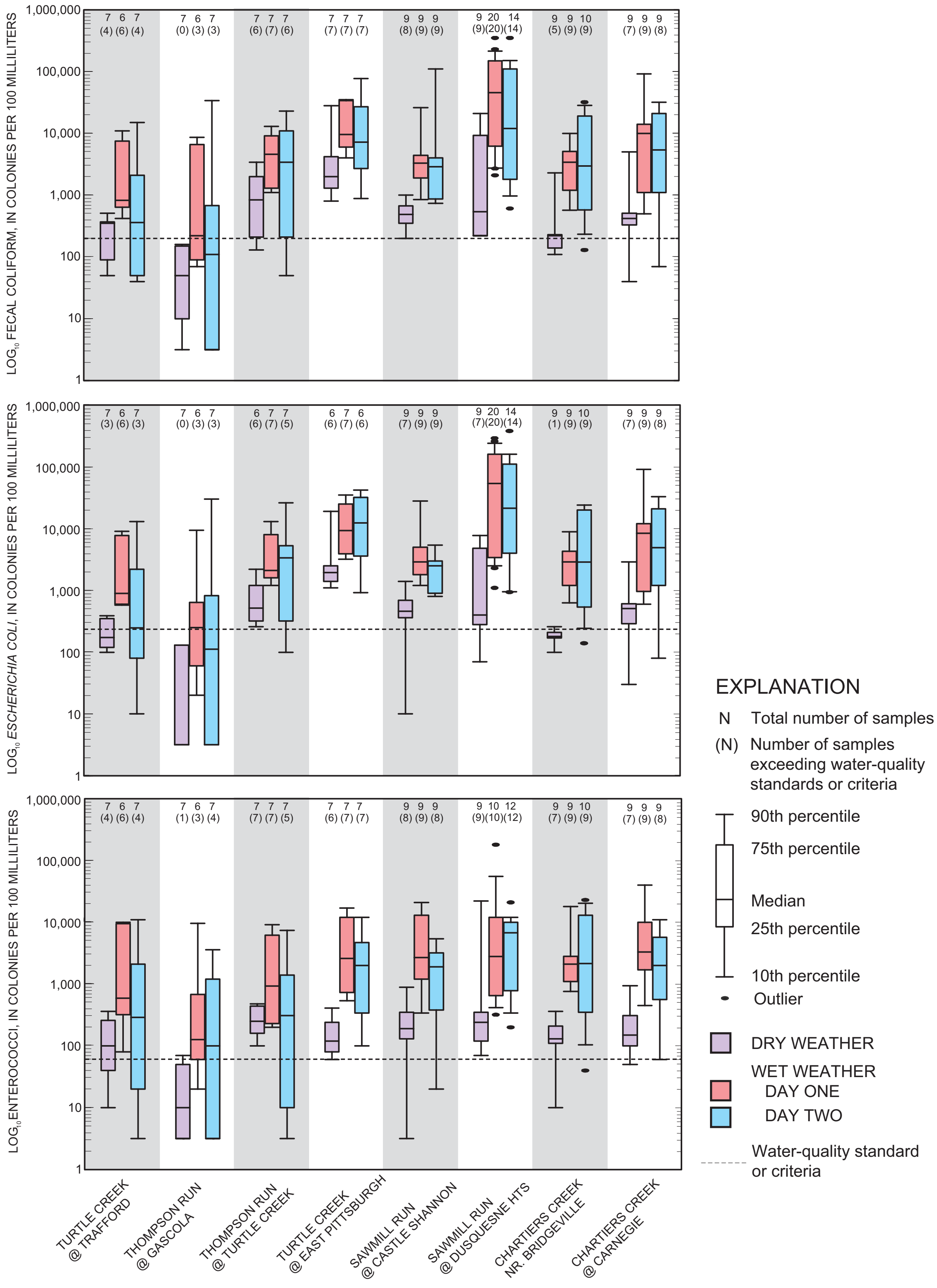

Figure 3. Fecal-indicator bacteria colonies in composite samples collected during dry and wet weather on Turtle Creek, Thompson Run, Sawmill Run, and Chartiers Creek, Allegheny County, Pennsylvania, 2004–2005.

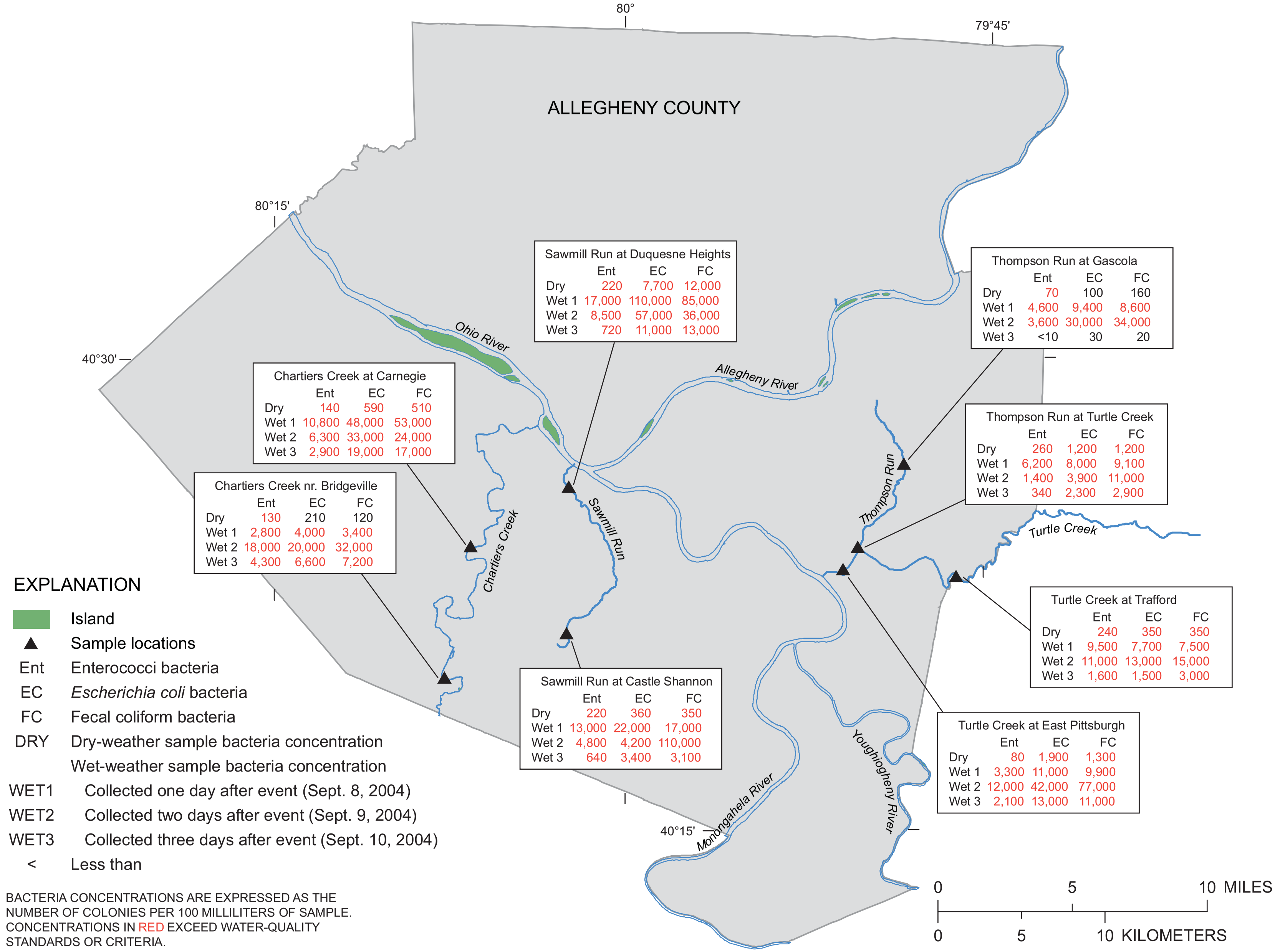

Figure 4. Concentrations of fecal-indicator bacteria in samples collected during dry weather on September 7, 2004, and wet weather on September 8, 9, and 10, 2004, from eight sites on Chartiers Creek, Sawmill Run, Thompson Run, and Turtle Creek, Allegheny County, Pennsylvania.

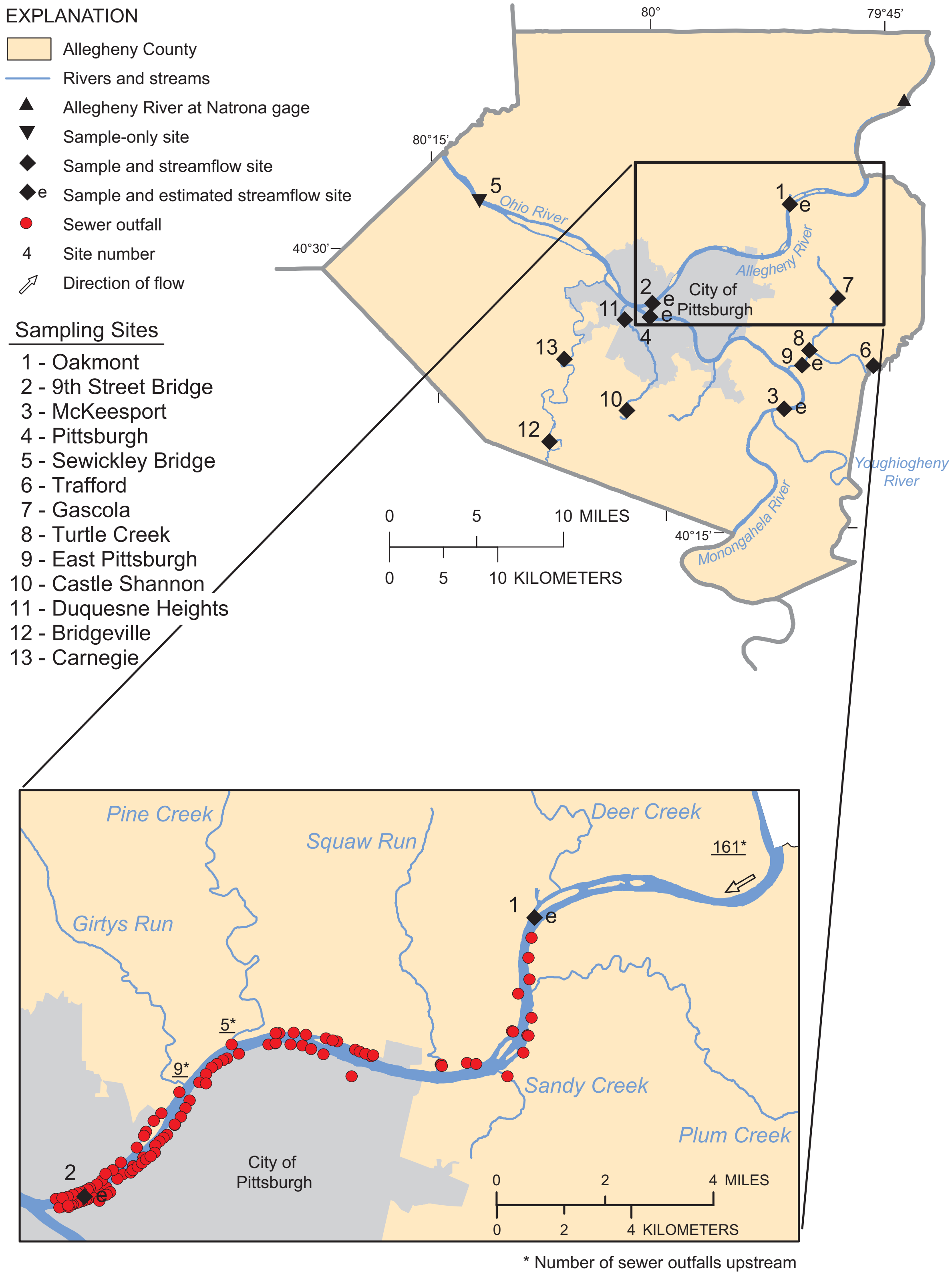

Figure 5. Locations of data-collection sites and sewer outfalls on the Allegheny River, Allegheny County, Pennsylvania.

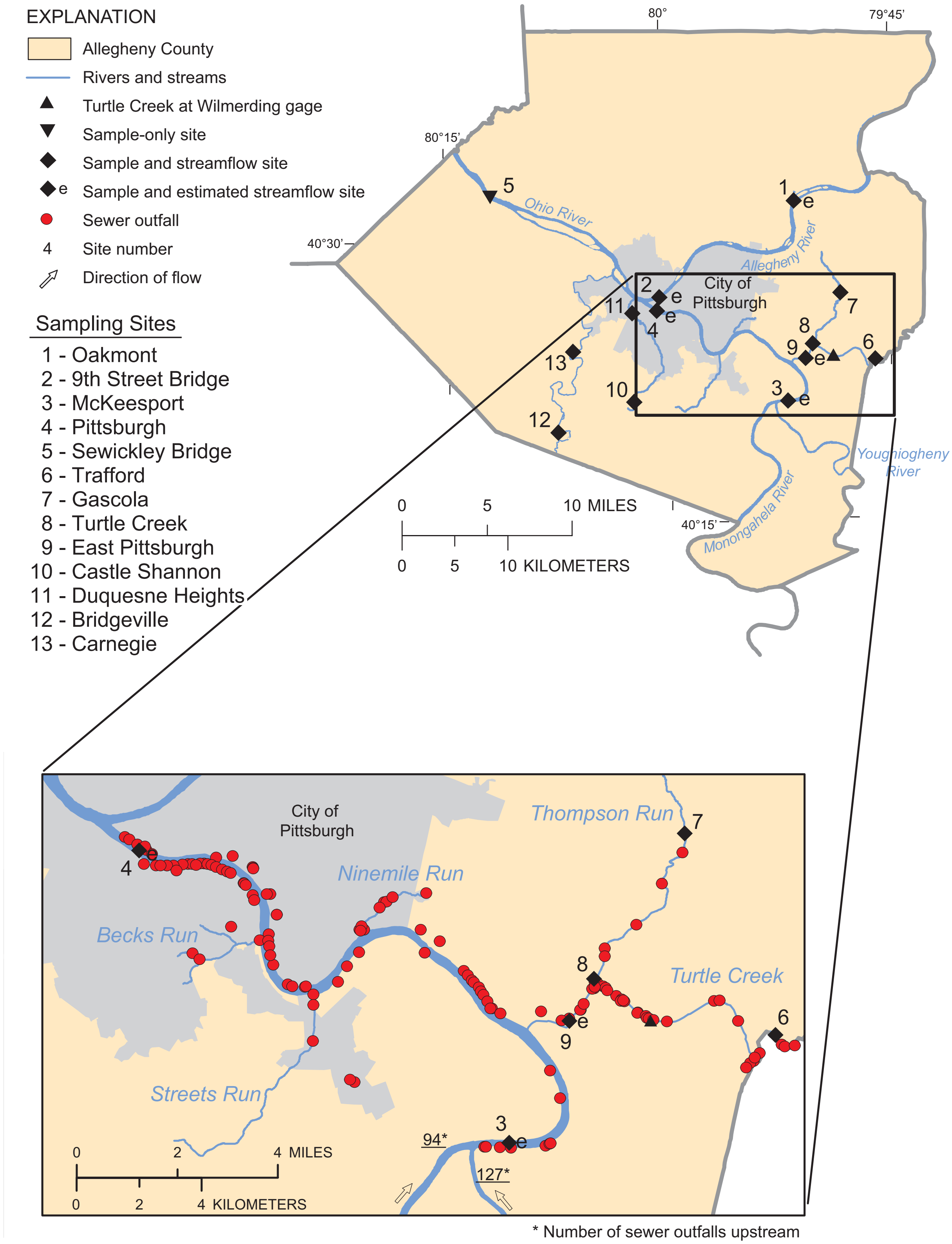

Figure 6. Locations of data-collection sites and sewer outfalls within the Monongahela River, Turtle Creek, and Thompson Run watersheds, Allegheny County, Pennsylvania.

tained concentrations of fecal coliform, *E. coli*, and enterococci of 410,000, 510,000, and 180,000 col/100 mL, respectively.

Correlation tests were done to determine if field characteristics were related to concentrations of fecal-indicator bacteria. The strongest correlations were between fecal-indicator bacteria concentrations and streamflow, specific conductance, and turbidity and generally were found in data from the tributary sites. For example, statistically significant correlations were observed between fecal coliform, *E. coli*, and enterococcus bacteria and specific conductance at Chartiers Creek near Bridgeville; Spearman's rho correlation coefficients were -0.811, -0.857, and -0.813, respectively. Weaker correlations existed between fecal-indicator bacteria and other variables at all sites, as indicated by smaller values of Spearman's rho.

Comparisons were made between results of analyses of composite samples collected during dry- and wet-weather conditions in the Three Rivers and selected tributary sites. Overall, about 35 percent of the composite samples collected from the Three Rivers sites and 13 percent of the composite samples collected from the tributary sites had bacteria concentrations that did not exceed any established recreational water-quality standards or criteria. Median concentrations of bacteria generally were higher in the wet-weather day-one composite samples and above water-quality standards or criteria compared to the dry-weather or wet-weather day-three composite samples at the Three Rivers site; median bacteria concentrations generally were above water-quality standards or criteria in the dry-weather and wet-weather composite samples at the eight tributary sites. Composite samples collected at the upstream sites on the Three Rivers and on selected tributaries generally had lower median concentrations of bacteria than composite samples collected at the downstream sites during dry- and wet-weather events. Higher concentrations downstream may be caused by discharge from the large number of sewer outfalls in the reach between the upstream and downstream sites.

Comparisons also were made among concentrations of fecal-indicator bacteria and turbidity in right-bank and composite samples, left-bank and composite samples, and right-bank and left-bank samples collected during dry- and wet-weather conditions at the Three Rivers sites. More statistically significant differences in data (12 total—4 in dry weather, 8 in wet weather) were observed in samples collected at Allegheny River sites than at Monongahela River sites or the Ohio River at Sewickley; most differences were between bank and composite samples as opposed to differences between right-bank and left-bank samples. Bacteria concentrations at the Allegheny sites typically were higher in the bank samples than in the composite samples during dry- and wet-weather events. This finding is an indication that bacteria from near-shore inputs tended to remain near the shore, regardless of weather conditions. In samples collected at Monongahela River at Pittsburgh, significant differences were observed in enterococci bacteria concentrations during dry-weather conditions and in turbidity measurements during wet-weather conditions between left-bank and composite samples (p-values of 0.019 and 0.074, respectively). During dry-weather conditions at Monongahela River at Pittsburgh, higher enterococci concentrations in left-bank compared to composite samples indicated that near-shore bacteria inputs tend to stay near the shoreline. During wet-weather conditions at Monongahela River at Pittsburgh, lower turbidity measurements in left-bank compared to composite samples indicated there may be a dilution effect near the shoreline as bacteria and sediment are being flushed further out into the stream channel. Statistical differences in concentrations of enterococci and fecal coliform bacteria between cross-sectional sampling locations were observed during dry-weather events only at the Ohio River at Sewickley. Concentrations of bacteria in samples from the Ohio River at Sewickley typically were higher in the left-bank samples than in the right-bank or composite samples during dry-weather events. Similar to findings at Monongahela River at Pittsburgh, this is an indication that bacteria from near-shore inputs tended to hug the left bank during dry-weather conditions.

A variety of point and nonpoint sources of fecal-indicator bacteria likely contribute to concentrations in the Three Rivers and selected tributaries. Point sources of fecal-indicator bacteria likely include sewer outfalls; nonpoint sources of bacteria likely include sewage discharging to tributary streams, malfunctioning sewage-treatment plants or overflows, leaking sewer lines, malfunctioning on-lot sewage systems, agricultural runoff, and wildlife. A study is underway between ALCOSAN, ACHD, and the USGS to determine the sources of *E. coli* contamination to the Three Rivers that will include the development of a water-quality model to predict bacteria concentrations. Additional data collection that would incorporate more wet-weather sampling and sampling from additional Three Rivers tributaries would also provide information helpful in defining the length of time concentrations of bacteria remain elevated after a wet-weather event.

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