Fecal–Indicator Bacteria in the Allegheny, Monongahela, and Ohio Rivers, near Pittsburgh, Pennsylvania, July-September 2001

by John W. Fulton and Theodore F. Buckwalter

In cooperation with the Allegheny County Health Department

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Conversion Factors and Abbreviations

Multiply	By	To obtain
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

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

°F = (1.8 · ° C) + 32

Concentrations of bacteria are given in colonies per 100 milliliters (col/100 mL), which is the same as colony forming units per 100 milliliters (CFU/100 mL).

Other abbreviations used in report:

ACHD	Allegheny County Health Department
ADCP	Acoustic Doppler current profiler
cm	centimeter
CSOs	Combined Sewer Overflows
CWA	Clean Water Act
E. coli	*Escherichia coli*, a fecal-indicator bacterium
EDI	equal discharge increment
FC	Fecal coliform
L	liter
m	meters
mL	milliliters
MPN	Most probable number
NASQAN	National Stream Quality Accounting Network
NAWQA	National Water-Quality Assessment
NWS	National Weather Service
ORSANCO	Ohio River Valley Water Sanitation Commission
PaDEP	Pennsylvania Department of Environmental Protection
Q	Discharge
QAPP	Quality Assurance Project Plan
SSOs	Sanitary Sewer Overflows
TMDL	Total Maximum Daily Load
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WQS	Water-Quality Standard
WWTP	Wastewater-treatment plant

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Abstract

This report presents the results of a study by the Allegheny County Health Department (ACHD) and the U.S. Geological Survey (USGS) to determine the concentrations of fecal-indicator bacteria in the Allegheny, Monongahela, and Ohio Rivers (Three Rivers) in Allegheny County, Pittsburgh, Pa. Water-quality samples and river-discharge measurements were collected from July to September 2001 during dry- (72-hour dry antecedent period), mixed-, and wet-weather (48-hour dry antecedent period and at least 0.3 inch of rain in a 6-hour period) conditions at five sampling sites on the Three Rivers in Allegheny County. Water samples were collected weekly to establish baseline conditions and during successive days after three wet-weather events.

Water samples were analyzed for fecal-indicator organisms including fecal-coliform (FC) bacteria, *Escherichia coli (E. coli)*, and *enterococci* bacteria. Water samples were collected by the USGS and analyzed by the ACHD Laboratory. At each site, left-bank and right-bank surface-water samples were collected in addition to a composite sample (discharge-weighted sample representative of the channel cross section as a whole) at each site. Fecal-indicator bacteria reported in bank and composite samples were used to evaluate the distribution and mixing of bacteria-source streams in receiving waters such as the Three Rivers.

Single-event concentrations of *enterococci*, *E. coli*, and FC during dry-weather events were greater than State and Federal water-quality standards (WQS) in 11, 28, and 28 percent of the samples, respectively; during mixed-weather events, concentrations of fecal-indicator bacteria were greater than WQS in 28, 37, and 43 percent of the samples, respectively; and during wet-weather events, concentrations of fecal-indicator bacteria were greater than WQS in 56, 71, and 81 percent of samples, respectively.

Single-event, wet-weather concentrations exceeded those during dry-weather events for all sites except the Allegheny River at Oakmont. For this site, dilution during wet-weather events or the lack of source streams upgradient of the site may have caused this anomaly. Additionally, single-event concentrations of *E. coli* and FC frequently exceeded the WQS reported during wet-weather events.

It is difficult to establish a short-term trend in fecal-indicator bacteria concentrations as a function of time after a wet-weather event due to factors including the spatial variability of sources contributing fecal material, dry-weather discharges, resuspension of bottom sediments, and flow augmentation from reservoirs. Relative to *E. coli* and *enterococci*, FC concentrations appeared to decrease with time, which may be attributed to the greater die-off rate for FC bacteria.

Fecal-indicator bacteria concentrations at a site are dependent on the spatial distribution of point sources upstream of the station, the time-of-travel, rate of decay, and the degree of mixing and resuspension. Therefore, it is difficult to evaluate whether the left, right, and composite concentrations reported at a particular site are significantly different. To evaluate the significance of the fecal-indicator bacteria concentrations and turbidity reported in grab and composite samples during dry-, mixed-, and wet-weather events, data sets were evaluated using Wilcoxon rank sum tests. Tests were conducted using the fecal-indicator bacteria colonies and turbidity reported for each station for a given weather event. For example, fecal coliform counts reported in the left-bank sample were compared against the right-bank and composite samples, respectively, for the Ohio River at Sewickley site during dry-, mixed-, and wet-weather events.

The statistical analyses suggest that, depending on the sampling site, the fecal-bacteria concentrations measured at selected locations vary spatially within a channel (left bank compared to right, right bank compared to composite). The most significant differences occurred between fecal-indicator bacteria in the left bank compared to composite and right bank compared to composite samples (p-values = 0.003 to 0.1), suggesting that during some wet- and dry-weather events, the mixing of source streams and the receiving water is incomplete. Turbidity (p-values = 0.003 to 0.1) and *enterococci* (p-values = 0.007 to 0.02) most frequently demonstrated a correlation between sample locations (left bank versus composite). Correlations between left-bank and right-bank samples were rare.

Introduction

Fecal-indicator bacteria in surface water collected from the Allegheny, Monongahela, and Ohio Rivers (Three Rivers) near Pittsburgh, Pa., periodically exceed state and Federal water-quality standards (WQS) for recreational waters (Siwicki, 2002). Because individual pathogens are difficult to measure directly (Chapra, 1997, p. 504), monitoring programs commonly rely on the detection of indicator organisms to serve as a surrogate of water quality. If indicator organisms are present, it is assumed more harmful pathogens such as bacteria, viruses, and protozoans may coexist in the water body.

Pathogens may be present in recreational waters or drinking-water supplies. Exposure to pathogens in water can have adverse effects on humans. During contact with recreational water, excessive amounts of bacteria can result in an increased risk of gastrointestinal, respiratory, eye, ear, throat, and skin diseases. Drinking water containing pathogens also may pose a risk, but public-water supplies must pass state drinking-water standards prior to distribution. Most bacteria can be removed by the use of chlorine, ion exchange, filtration, and reverse osmosis, but treatment costs can be excessive. The protozoans *Cryptosporidium parvum* and *Giardia lamblia* are resistant to chlorine and require supplemental filtration. Filter-feeding shellfish, including clams, oysters, and mussels, concentrate microbial contaminants in their systems and may be harmful to humans when consumed raw or uncooked (U.S. Environmental Protection Agency, 2001).

Fecal-indicator bacteria include a variety of coliform bacteria and streptococcus bacteria. Traditionally, total coliform is the most widely used parameter for monitoring; however, its use is problematic becauseof nonfecal coliform bacteria. Organisms more indicative of intestinal contamination such as *enterococci*, *Escherichia coli (E. coli)*, and fecal coliform (FC) are preferred. Each can be sampled and quantified using standard methods and are relatively abundant in human and animal waste. Because the die-off rates for *enterococci* and *E. coli* are less than that of FC, they provide a better measure of the risk of gastrointestinal illness related to recreational contact (U.S. Environmental Protection Agency, 2001).

Federal regulations require public notice when sewer overflows and runoff increase the likelihood of river contamination. Since 1995, the Allegheny County Health Department (ACHD) has issued river-water advisories to warn of possible river contamination and to caution people to limit contact with river water when boating, fishing, skiing, swimming, or engaging in other river recreational activities. An advisory does not prohibit nor discourage river recreational activities; instead, it is intended to inform the public when river water may be contaminated so that precautions can be taken to minimize water contact. Advisories are issued during the summer river-recreation season, which lasts from May 15 to September 30, when sewer overflows and storm runoff increase the likelihood of river contamination. During the summer of 2000, when precipitation was above normal, 13 advisories were issued, lasting 71 out of a total of 138 days.

Bacteria concentrations in the Three Rivers need to be measured to alert users of potential pathogen concentrations. The U.S. Geological Survey (USGS) in cooperation with the ACHD began a project in July 2001 to assess fecal-indicator bacteria contamination of the Three Rivers in Allegheny County, Pa. The project was supported using funds allocated through Section 104(b)(3) of the Clean Water Act (CWA) and administered by the U.S. Environmental Protection Agency (USEPA) and the Pennsylvania Department of Environmental Protection (PaDEP).

Purpose and Scope

This report (1) establishes sampling protocols for monitoring receiving water; (2) presents the *E. coli*, *enterococci*, and FC bacteria data collected from five sites in the Three Rivers from July to September 2001; (3) evaluates the distribution of bacteria in receiving water; (4) determines the effects of wet weather on bacteria colonies; (5) compares the bacteria data to WQS; and (6) estimates daily loads of fecal-indicator bacteria. Water-quality samples were collected and streamflow was measured during dry-, mixed-, and wet-weather conditions at five sampling sites in the Three Rivers in Allegheny County. Samples were collected weekly to establish baseline conditions and during successive days after three wet-weather events. The samples after wet-weather events were collected on the following dates: August 8, 9, and 10; August 29 and 30; and September 25, 26, 27, and 28.

Description of Study Area

The study area includes portions of the Allegheny, Monongahela, and Ohio Rivers, which are the large rivers entering and exiting Allegheny County (fig. 1). Allegheny County has an area of about 730 mi^2. Pittsburgh, the county seat, is near the center of the county, where the Allegheny and Monongahela Rivers join to form the Ohio River.

Allegheny County is in a rugged section of the Allegheny Plateau Physiographic Province. Stream erosion has created a complexly dissected area having as much as 650 ft of relief between hilltops and valley bottoms. The tributary streams generally lie in V-shaped valleys, and their gradients are much steeper than those of the major streams. These steep gradients facilitate rapid urban runoff after precipitation.

The 2000 census listed 1,281,666 people in the county and 334,563 in the city of Pittsburgh (U.S. Census Bureau, 2003, accessed April 29, 2003).

Annual precipitation for Pittsburgh averages 37 in. The Allegheny River serves as the source of water supply for the city of Pittsburgh. The Monongahela River is the source of water for the Pennsylvania American Water Company, which serves large areas of Allegheny County to the south of the city of Pittsburgh. Several municipalities pump water from wells adjacent to the Three Rivers for water supply.

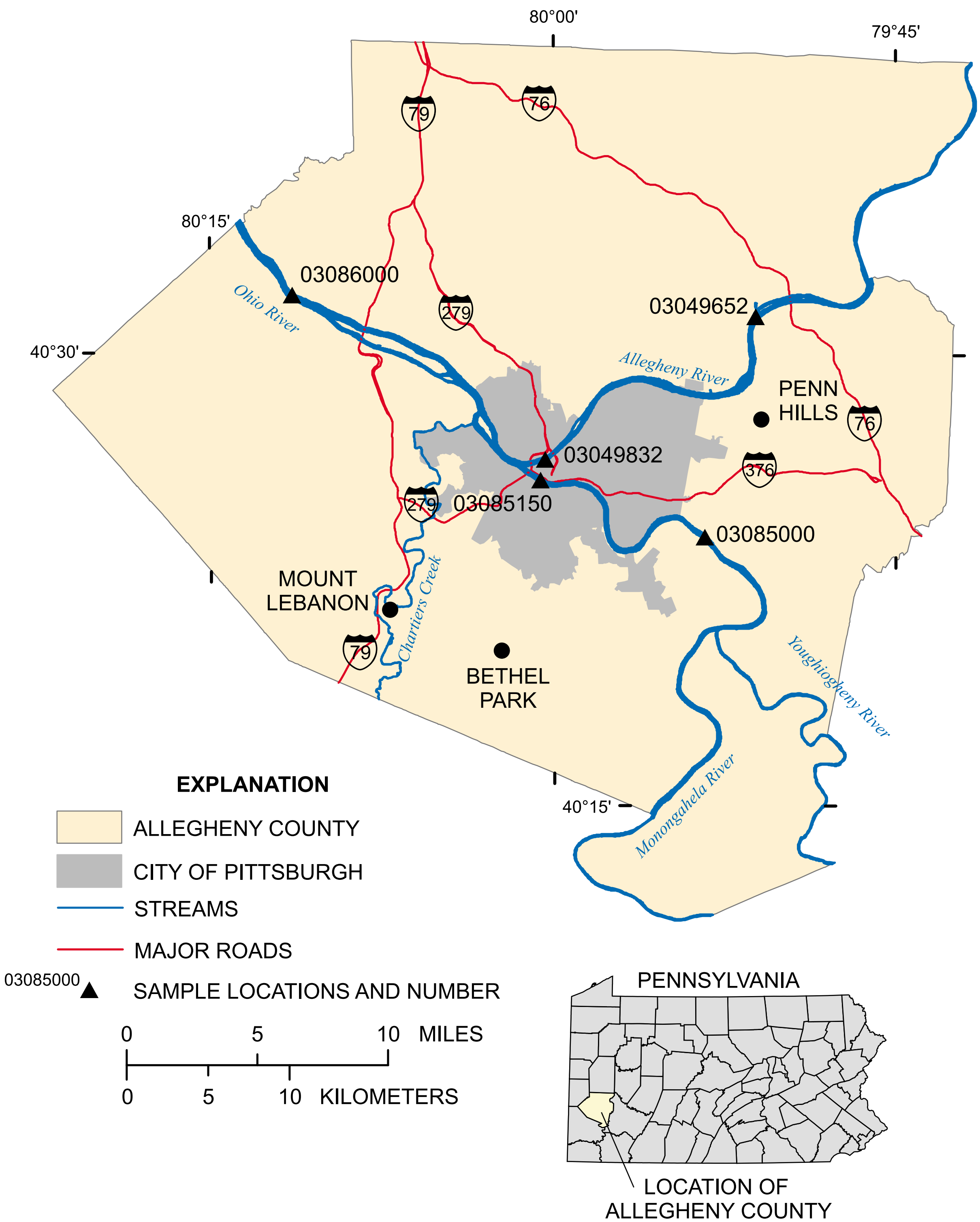


Figure 1. Study area and location of sampling sites on the Allegheny, Monongahela, and Ohio Rivers region near Pittsburgh, Pennsylvania.

Water-Quality Criteria

The PaDEP (25 Pa. Code §93.7) has established the following WQS for bacteria: from May 1 through September 30, FC shall not exceed a geometric mean of 200 col/100 mL from five consecutive samples in a 30-day period. From October through April, FC shall not exceed 2,000 col/100 mL. Pennsylvania presently (2004) lacks recreational water-quality criteria for *E. coli* and *enterococci* in surface water. The USEPA (1986) has issued recommended criteria for *E. coli* of 126 col/100 mL and *enterococci* of 33 col/100 mL in recreational waters. Both are represented as a geometric mean based on not less than five samples equally spaced over a 30-day period.

Given the objectives of this project, the collection of five samples, equally spaced over a 30-day period, was not attempted. Rather, the project was designed to measure the effects of dry- and wet-weather events on the quality of the receiving waters within the region. Because the timing of dry- and wet-weather events did not coincide with regular, weekly sample events, the WQS specified above were used as a metric and not a compliance criteria. Town (2001) adopted this modification of the 1986 USEPA criteria for other fecal-indicator studies in recreational waters in Pennsylvania.

Previous Work

Federal, local, and private agencies have conducted bacteria monitoring of the Three Rivers. On the basis of historical data, the highest concentrations of FC generally are during the summer months after storm events, when the WQS are most stringent for the Allegheny and Monongahela Rivers. A review of past and present programs follows.

Ohio River Valley Water Sanitation Commission (ORSANCO)

Since 1992, bacteriological monitoring in the Ohio River has been conducted by ORSANCO, an interstate commission representing the Federal government and eight member states that border the Ohio River Basin.

From May through October each year, surface-water grab samples are collected at mid-stream at river mile 4.3 (distance in miles measured downstream from the confluence of the Allegheny and Monongahela Rivers in Pittsburgh) at a frequency of five per month. From 1992 to 1999, samples were analyzed for FC only; analysis for *E. coli* started in 2000. During the period from 1992 through 2001, the minimum, maximum, and median concentrations of FC were 4; 35,000; and 330 col/100 mL, respectively. The minimum, maximum, and median concentrations of *E coli* were 150; 27,000; and 150 col/100 mL, respectively (Ohio River Valley Water Sanitation Commission, oral commun., 2002).

U.S. Geological Survey

The USGS participated in two programs in the Three Rivers area near Pittsburgh, Pa., that included sampling and analysis for indicator bacteria.

- From 1976 through 1989, USGS partnered with the USEPA to operate a surveillance network at the Allegheny River at New Kensington, Pa., and Monongahela River at Braddock, Pa. The same sites were sampled from 1989 through 1994 as part of another USGS program, the National Stream Quality Accounting Network (NASQAN). The sites were operated in 1995 as part of the USGS National Water-Quality Assessment (NAWQA) Program. During each program, surface-water samples were collected mid-stream at a frequency of one per month or quarterly and analyzed for concentrations of FC and fecal streptococci. From 1976 through 1995, the median concentration of FC at New Kensington was 225 col/100 mL. The median concentration of FC at Braddock was 1,200 col/100 mL.
- From 1980 through 1995, 72 percent of the FC samples collected at New Kensington from May through September exceeded the WQS of 200 col/100 mL; only 2.3 percent of the samples collected from October through April exceeded the 2,000 col/100 mL WQS. Similarly, 97 percent of the samv ples collected at Braddock from May through September exceeded 200 col/100 mL; only 7.8 percent of the samples collected from October through April exceeded 2,000 col/100 mL (U.S. Geological Survey, 2002).

The above data show that concentrations of fecal-indicator bacteria exceeded WQS established by PaDEP and USEPA; however, the influence of dry- and wet-weather events was not a focus of these efforts.

Local Efforts

Bacteria monitoring has been implemented by a variety of local groups, including water companies, ACHD, and 3 Rivers – 2nd Nature, STUDIO for Creative Inquiry (3R2N), part of the College of Fine Arts of Carnegie Mellon University. The bacteria data collected by the water companies and ACHD are unpublished. 3R2N issues annual reports summarizing water-quality data for the Three Rivers and selected tributary sites. The program is a multiyear effort focusing on different navigation pools within the Three Rivers region. Sample sites are dependent on public access and inflow points discharging to the Three Rivers. Water-quality constituents sampled by this program include total coliform, *E. coli*, *enterococci*, pH, temperature, specific conductance, and dissolved oxygen.

In addition to water-quality sampling, the group has attempted to establish a relation between historical use and human activities that has influenced changes in the river system over time. Ultimately, 3R2N will identify a range of baseline practices with clearly defined social-political strategies, designed to enable communities to be involved in determining the future of their rivers and waterfronts. Knauer and others (2000) provided a summary of findings that includes fecal-indicator bacteria sampling during the summer of 2001 from sites on the Monongahela River from river mile 11.5 to 35.0 and on selected tributary streams to the Monongahela River.

Related Studies

Similar studies of fecal-indicator bacteria have been initiated by the USGS in other regions of the country. Myers and others (1998) evaluated the effects of stormwater, CSOs, and wastewater-treatment discharges on the middle main stem of the Cuyahoga River between Akron and Cleveland, Ohio. Their results suggest that fecal-indicator bacteria frequently exceeded Ohio's WQS for recreation during rainfall and runoff periods. Decay, transport, dilution, and dispersion of fecal bacteria were evaluated in the Cuyahoga River to estimate spatial and temporal variations in concentration. Decay rates ranged from 0.0018 hr^{-1} to 0.0372 hr^{-1} for FC and from 0.0022 hr^{-1} to 0.0407 hr^{-1} for *E. coli*. Additionally, decay rates reported in June and August 1992 were significantly higher than those measured in April and October 1992. The importance of streambed sediments as a source of bacteria loading was assessed by collecting and enumerating fecal-indicator bacteria at two locations in the Cuyahoga River. Concentrations of fecal-indicator bacteria in the sediments were from 1.2 to 58 times more concentrated per unit weight than in the overlying water column.

Effects of wastewater and CSOs on *E. coli* concentrations were evaluated in the Blue River Basin, Kansas City, Mo., and Kansas from July 1998 to October 2000 during base flow (Wilkison and others, 2002). The median concentrations of *E. coli* of 800 col/100 mL on the Blue River and 490 col/100 mL on Brush Creek exceeded the USEPA WQS. Genetic fingerprint patterns of *E. coli* from selected stream samples were compared to a data base of known source patterns to determine possible sources of bacteria. Presumptive sources of *E. coli* were almost equally divided among dogs (28.3 percent), geese (22.1 percent), humans (23.4 percent), and unknown sources (26.2 percent).

The USGS, in cooperation with the National Park Service, began a 2-year study in 1999 to evaluate microbial contamination in streams in and near the Chattahoochee River National Recreation Area, Ga. Synoptic surveys indicated the lowest FC concentrations in Chattahoochee River and tributaries during low-flow conditions; in contrast, the highest FC concentrations occurred during stormflow conditions (Gregory and Frick, 2001). During diurnal sampling, indicator-bacteria concentrations were lowest during late afternoon, following the period of most intense sunlight, and highest during the night. Concentrations of FC, *E. coli*, and *enterococci* were approximately 4, 6, and 8 times higher, respectively, during the night than when sunlight intensity was highest. Daily fluctuations in sunlight intensity may influence indicator-bacteria concentrations during low-flow conditions and in shallow water.

Sources of Bacteria

Some potential sources of pathogens to receiving waters such as the Three Rivers are listed below. They can be categorized as point sources and nonpoint sources.

- combined sewer overflows (CSOs)
- sanitary sewer overflows (SSOs)
- overflows from wastewater treatment plants (WWTP)
- illicit sewage connections
- base flow and direct runoff from urban, agricultural, and forested basins
- wildlife and livestock
- landfills
- septic systems
- pet waste
- waterfowl
- sanitary sewer leaks

Point Sources

Point-source discharges typically are associated with end-of-pipe releases. Of these, raw sewage poses the greatest potential source of human pathogens. Novotny and others (1989, p. 2-6) reported concentrations of total coliform in sewage ranged from 10^7 to 10^9 MPN (most probable number) /100 mL. Proportionally high concentrations of pathogenic organisms, including bacteria, viruses, protozoans, and other parasites, are associated with raw sewage (U.S. Environmental Protection Agency, 2001). The most common pathways for introducing sewage into a receiving water include wet-weather overflows from CSOs, SSOs, illicit sewage connections, and WWTP effluent.

Combined sewers are water-collection systems designed to convey stormwater and wastewater from domestic, commercial, and industrial sources in a single pipe to a WWTP. During wet weather, the distribution system or WWTP can be hydraulically overloaded, resulting in the direct discharge of untreated stormwater and wastewater to a receiving water. In contrast, sanitary sewers are designed to carry only wastewater. Illicit piping of storm drains, parking areas, and roof and foundation laterals (inflow) can trigger overflows to receiving waters, streets, or basements. Dry-weather discharges also may occur in CSOs and SSOs, when inflow and excess ground water or surface water are introduced by infiltration through cracks, joints, and breaks in the piping network. The discharge volume and concentration are dependent on the duration and antecedent conditions prior to a precipitation event. Typical concentrations of total coliform bacteria in CSOs range from 10^5 to 10^7 MPN/100 mL (Novotny and others, 1989, p. 2-6).

WWTPs typically reduce total coliform counts of raw wastewater by approximately three orders of magnitude to 10^4 to 10^6 MPN/100 mL (U.S. Environmental Protection Agency, 2001); however, periodic overflows of effluent during high flows could contribute higher concentrations of bacteria to rivers and tributaries. Wastes from slaughterhouses, dairy farms, and meat and poultry processing plants also could contribute pathogenic loads to waterbodies.

Nonpoint Sources

Nonpoint sources of fecal contamination are diffuse. In rural areas, the principal source of fecal matter is runoff from confined animal operations (U.S. Environmental Protection Agency, 2001); however, leachate in runoff from failing or illicitly connected septic tanks and leachate from livestock, pastures, rangelands, uncontrolled manure storage areas, and wildlife also contribute significantly to bacteria in stream base flow and stormflow. Beaver, deer, and waterfowl also contribute pathogens to receiving waters.

Because urban basins contain impervious areas engineered with drainage controls, stormwater runoff can transport fecal matter associated with litter, domestic pets, and wildlife. Coliform concentrations in urban stormwater are consistent with those reported in WWTP effluent (U.S. Environmental Protection Agency, 2001). Young and Thackston (1999) determined that fecal-bacterial loading in urban streams was a function of the density of housing, population, development, impervious cover, and domestic animal population.

Resuspension of bacteria-laden sediment is of particular concern in large rivers systems such as the Three Rivers. The pools created by lock and dam systems act as settling basins. Depending on grain size and organic content, sediment within a receiving water may serve as a reservoir for bacteria. Weiskel and others (1996) reported an increase in FC density in Buttermilk Bay, Mass., where the most prolific increases were associated with sites in which the sediment consisted of fine-grained, high-organic carbon muds. This suggests an affinity for bacteria to adsorb onto the surfaces of fine-grained sediments prior to being mobilized.

Bacteria-laden sediment could be resuspended in the water column in a variety of ways including high flows triggered by reservoir releases, direct runoff attributed to precipitation, recreational and commercial boat traffic, lock and dam operations, and scour related to an increase of instream flow and velocity. Yagow and Shanholtz (1998) reported that increasing bacteria concentrations in the water column coincided with decreasing concentrations in stream sediments. The sediments were then deposited downstream, where bacteria concentrations in the sediment increased and concentrations in the water column returned to background levels. Depending on the degree of hydraulic connection between ground water and surface water, base flow may transport fecal loads to surface-water bodies.

Fate and Transport

A variety of factors influence the fate and transport of pathogens and ultimately their concentration within a receiving water. Physical, chemical, and biologic conditions that include sunlight, temperature, moisture conditions, salinity, bottom sediments, and related hydraulics of the receiving water affect pathogen die-off rates. Additionally, contaminant pathways influence attenuation rates by exposing pathogens to conditions that may not be favorable for survival.

The factors that are most significant in determining pathogen die-off rates are sunlight (ultraviolet and near-ultraviolet radiation), temperature, and moisture. Increased rates of ultraviolet radiation increase die-off rates in bacteria and viruses (U.S. Environmental Protection Agency, 2001). Suspended sediment will scatter sunlight. As a result, the effect of sunlight is limited by its penetration depth within the water column. For example, the die-off rate for bacteria near the water surface will be greater than for bacteria near the channel bottom.

Survival of pathogen and indicator bacteria is dependent on ambient temperature (U.S. Environmental Protection Agency, 2001). The relation is an inverse one, suggesting that increasing temperatures result in decreasing survival rates. Gerba and Britton (1984) reported that die-off rates for coliform bacteria in soil doubled for each 10°C increase in temperature.

Bacteria survival times increase with moisture content and retention (Reddy and others, 1981). Therefore, soil with a high clay content will have a greater soil-moisture retention capacity and greater propensity for bacteria to proliferate.

Bottom sediments provide a safe haven for bacteria populations against radiation and temperature variations. Burton and others (1987) reported the number of indicator and pathogenic bacteria in bottom sediments is greater than that in the overlying water column. Sherer and others (1992) report the survival times for FC in bottom sediments is greater than those for the water column, suggesting that bacteria can survive in bottom sediments for extended periods of time compared to that of the water column. This reservoir allows bacteria to survive for up to several months, increasing the potential for recreational contact from resuspension. Survival rates for FC and fecal streptococci were significantly longer (11 to 30 days and 9 to 17 days, respectively, when incubated) in sediment-laden water than in water without sediment (U.S. Environmental Protection Agency, 2001).

Study Design

The study was designed to estimate bacteria concentrations in the large rivers entering and exiting Allegheny County. Additionally, it was important to establish the bacteria contributions of the Allegheny and Monongahela Rivers prior to their discharging to the Ohio River. Five sampling sites on the Three Rivers in Allegheny County near Pittsburgh, Pa., were chosen (fig. 1). Two sampling sites were selected along the Allegheny and Monongahela Rivers, respectively, and one site was selected along the Ohio River (table 1).

Site Selection

Sites that did not have previous streamflow or water-quality data include the Allegheny River at Oakmont (Oakmont), the Allegheny River at 9th Street Bridge (9th St. Bridge), and the Monongahela River at Pittsburgh (Smithfield St. Bridge). The location of the Allegheny River at Oakmont was selected, because it was upstream of a high density of CSOs on the riverbanks in the City of Pittsburgh, and because the Oakmont bridge permitted safe access of personnel and the cranes used to sample the river from the bridge. The locations of the Allegheny River at 9th Street Bridge and Monongahela River at Pittsburgh were selected to estimate the contributions of fecal-indicator bacteria of these rivers to the Ohio River. The Monongahela River at Braddock (Braddock) and the Ohio River at Sewickley (Sewickley) are active USGS streamflow-measurement stations where water-quality samples are collected (Siwicki, 2002).

Sampling Protocol

To measure fecal-indicator bacteria in large river systems, two factors were considered during development of the sampling protocol:

- Wet-, dry-, and mixed-weather conditions during low-base flow and high-base flow periods
- Mixing of point- and nonpoint-discharge sources with a receiving water

The study adopted the definitions of wet- and dry-weather conditions established by ORSANCO. Namely, a wet-weather event is characterized by at least a 48-hour dry antecedent period and at least 0.3 in. of precipitation in a 6-hour period; a dry-weather event is dominated by at least a 72-hour dry antecedent period. Additionally, only those storms that encompassed large parts of Allegheny County were selected. In some cases, samples were collected under mixed-weather conditions that did not meet the above constraints.

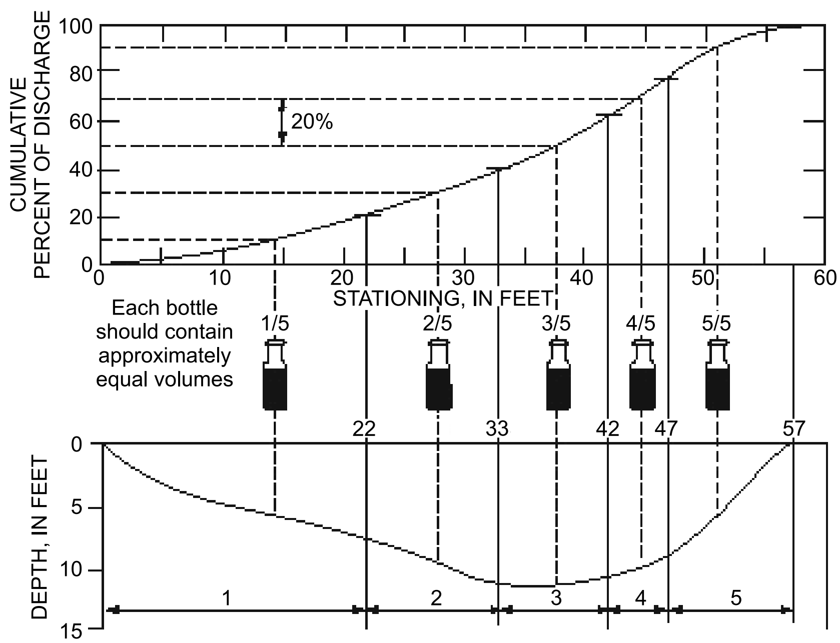
The degree of mixing played a significant role in establishing sample locations. Under poorly mixed conditions, point discharges such as a tributary containing elevated bacteria concentrations may be strongly deflected by the receiving water and hug the side of the receiving water channel. Alternatively, under well-mixed conditions, one may expect peak concentrations to coincide with that part of a channel where the maximum velocity occurs.

Equal discharge-increment (EDI) sampling and grab sampling were utilized at each section. For each sampling event, three samples were collected at each site, one characteristic of the channel cross-section (EDI sample) and two grab samples near the left bank and right bank at each section (about 20 ft from shore at a depth of 18 in.). EDI samples provide an advantage over conventional grab samples in that they represent an integrated discharge-weighted sample. As a result, the concentration reported can be used in conjunction with the flow rate measured at the section to determine the load at the time of sampling. Details describing the EDI method are described by USGS (1997 to present) at *http://water.usgs.gov/usgs/publishing/Memos/memo2002_15.html*. The general process associated with the sampling method is shown in figure 2.

Table 1. Description of sampling sites on the Allegheny, Monongahela, and Ohio Rivers near Pittsburgh, Pennsylvania.

Site name	U.S. Geological Survey site identification number	Sample obtained from	River mile (miles)	Distance upstream to the Allegheny County border (miles)	Drainage area (square miles)
Allegheny River at Oakmont (Oakmont)	03049652	bridge	[1] 12.7	28	11,577
Allegheny River at 9th Street Bridge (9th St. Bridge)	03049832	boat	[1] .7	16	11,710
Monongahela River at Braddock (Braddock)	03085000	boat	[2] 11.2	25	7,337
Monongahela River at Pittsburgh (Smithfield St. Bridge)	03085150	boat	[2] .8	16	7,367
Ohio River at Sewickley (Sewickley)	03086000	bridge	[3] 13.3	3.6	19,500

[1] River miles are measured from the site to the mouth of the Allegheny River.
[2] River miles are measured from the site to the mouth of the Monongahela River.
[3] River miles are measured from the site to the confluence of the Allegheny and Monongahela Rivers.



Section Number	Sampling vertical bottle/ number	Percent discharge	Increment centroid from left edge of water, in feet	Increment depth, in feet
1	1/5	20	14	6
2	2/5	20	28	10
3	3/5	20	38	12
4	4/5	20	45	11
5	5/5	20	51	7

Figure 2. Cumulative percentage of discharge and stream cross section in an example of an equal discharge incremental (EDI) sample (modified from U.S. Geological Survey, 1997 to present, figure 4-3).

Sampling Protocol Evaluation

The sampling protocols that consisted of an EDI sample and separate left-bank and right-bank samples were selected on the basis of a variety of logistical concerns, cost efficiency, and informational needs. The ACHD and USGS agreed that point samples provide a discrete measure of concentrations of fecal-indicator bacteria, which are a function of depth and distance from the water's edge; however, because of cost constraints and the objective to estimate daily loads of fecal-indicator bacteria, composite samples rather than point samples were proposed as the procedure to routinely estimate the extent of bacterial contamination at a given sampling site.

A demonstration project was conducted at the request of the USEPA to compare EDI samples against samples that were not composited. The selected site was on the Ohio River at Sewickley near Pittsburgh, Pa. Two depth-integrated samples were collected at each of four stations along the cross section. Samples were combined (one from each of the four stations) to make up a composite sample using EDI techniques. The remaining samples from each station were processed and analyzed independently (discrete samples) (table 2).

Table 2. Comparison of bacteria concentrations in discrete and composite samples collected from the Ohio River at Sewickley, Pennsylvania.

[Bacteria concentrations in colony forming units per 100 milliliters]

Date	Station, in feet from river bank					
July 24, 2001 – Bridge Team	250	480	740	1,000	Mean	Composite sample concentration
Enterococci	10	3	15	5	8	3
Escherichia coli	3	5	90	40	34	15
Fecal coliform	20	15	120	15	43	40
August 28, 2001 – Bridge Team	250	480	750	1,010	Mean	Composite sample concentration
Enterococci	5	5	15	20	11	10
Escherichia coli	140	260	490	110	250	240
Fecal coliform	220	170	100	130	155	760
September 26, 2001 – Boat Team	243	453	768	1010	Mean	Composite sample concentration
Enterococci	15	10	50	10	21	20
Escherichia coli	600	440	2,100	2,100	1,310	2,000
Fecal coliform	2,600	420	4,700	3,100	2,705	3,200

Two primary conclusions can be drawn from the data presented: 1) bacterial concentrations vary across the width of the Ohio River at Sewickley and 2) EDI samples do not always approximate the mean of the quarter-point samples. In some instances, the comparability of the mean and composite sample was good with percentage differences as low as 4 percent. However, the percentage differences in some samples was as great as 167 percent. The need to use compositing techniques was confirmed, and the EDI technique was retained as the protocol for this project.

Streamflow Measurements

In an effort to establish appropriate EDI sample locations, real-time streamflow measurements were made at each section at selected times during the sampling program, where a period of record was absent (Allegheny River at Oakmont, Allegheny River at 9th Street Bridge, and Monongahela River at Pittsburgh) or where a boat site was stationed (Monongahela River at Braddock). Real-time measurements were made using an acoustic Doppler current profiler (ADCP) mounted to a boat. The ADCP unit transmits sound bursts at a fixed ultrasonic frequency of 600 kHz into the water column. Suspended particles in the water scatter the acoustic bursts back to the unit. As echoes return from deeper depths in the water column, the unit assigns various water depths to each echo record and measures the Doppler shift in the acoustic bursts. The resulting output provides a measure of the water velocity, depth, and discharge within open channels. When configured, the unit is capable of measuring the channel depth to within ± 10 cm or 0.33 ft and channel velocity to within 3 percent. The largest source of error is its inability to obtain velocity data near the water surface, channel bottom, and sides. An ADCP transect of the Monongahela River at Braddock is presented in figure 3 and was initiated at 0900 on August 28, 2001. The profile illustrates the velocity distribution captured by a tow barge passing upstream and the resultant propeller wash created by the barge. Streamflow was computed to be 5,670 ft^3/s.

At sections where streamflow is measured continuously (Ohio River at Sewickley and Allegheny River at Oakmont - estimates determined from the Allegheny River at Natrona, 11 mi upstream of Oakmont), velocity-distribution data were reviewed to establish appropriate EDI sample locations.

Ideally, time-of-travel estimates and hydrographs could be developed and reviewed for each site to ensure the sample time coincided with a point on the rising limb, at peak flow, and on the falling limb of the hydrograph. However, regulation of river flows by flood-control dams within the Three Rivers region and water withdrawals for power generation and water supply precluded this effort. These influences are illustrated in figure 4, which shows the streamflow recorded at the Sewickley streamflow-measurement station on the Ohio River during a period of no precipitation.

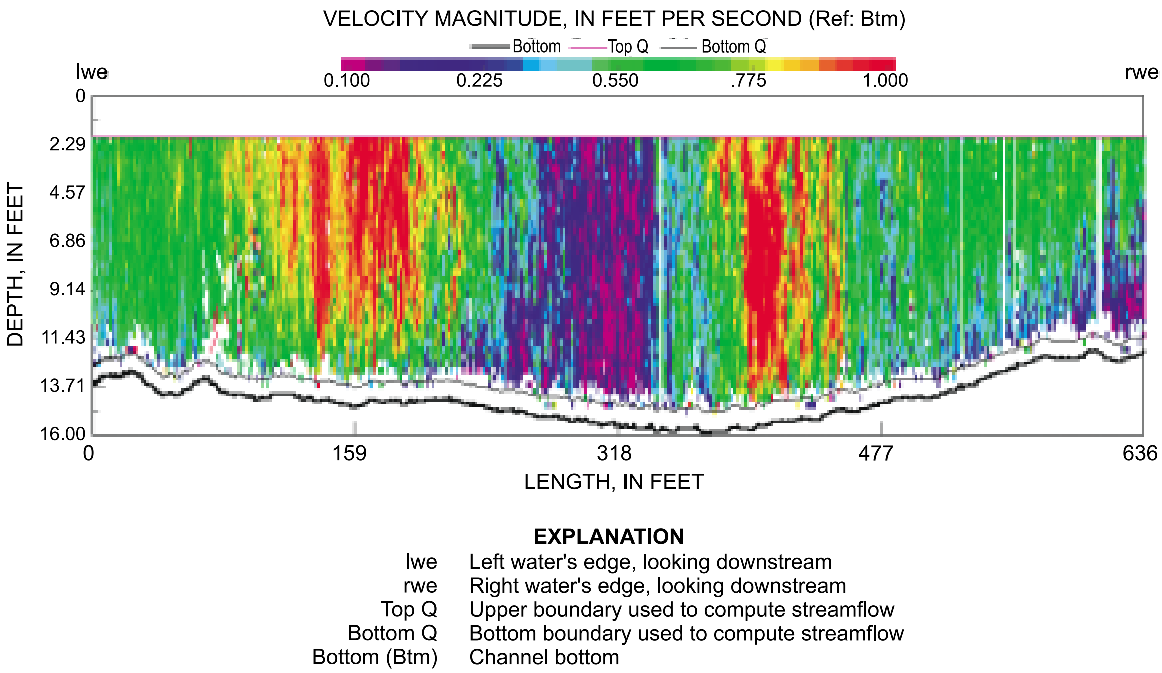


Figure 3. River cross-section and stream-velocity profile generated from acoustic Doppler current profiler, Monongahela River at Braddock, Pennsylvania, (03085000), August 28, 2001.

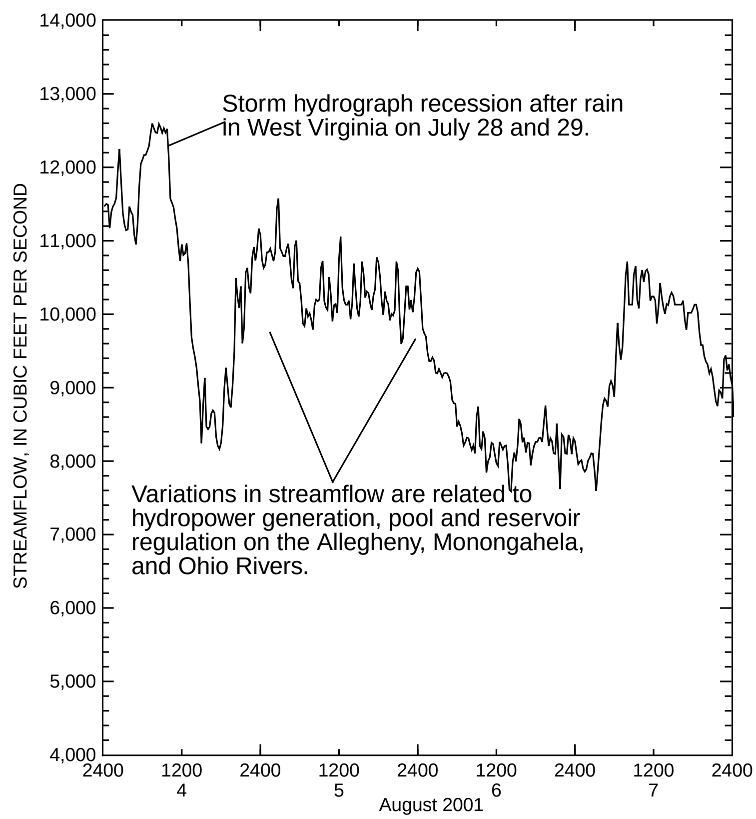


Figure 4. Hydrograph from the streamflow-gaging station on the Ohio River at Sewickley, near Pittsburgh, Pa., on August 4-7, 2001, prior to the August 8 wet-weather event.

Water-Quality Sampling Methods

Water samples were collected and analyzed for the following constituents: (1) FC bacteria, (2) *E. coli* bacteria, (3) *enterococci* bacteria, (4) turbidity, (5) specific conductance (SC), (6) temperature, (7) dissolved oxygen (DO), and (8) pH.

Field and quality-assurance methods were consistent with those referenced in the *National Field Manual for the Collection of Water-Quality Data* (Wilde and others, 1999) and in accordance with the approved Quality Assurance Project Plan (QAPP) and amendments issued to the USEPA prior to project initiation. The analyses of the fecal-indicator bacteria were performed using membrane filtration methods by laboratory staff of the ACHD. The procedures used for the analysis of FC bacteria are from Standard Methods for the Examination of Water and Wastewater by the American Public Health Association and others (1998, p. 9-63 to 9-65). The analysis of *enterococci* bacteria was done by the American Public Health Association and others (1998, p. 9-76 to 9-78). The methods used for *E. coli* bacteria (Method 1103.1 using mTEC Agar) were those of the USEPA (2000, p. 24-35).

Aseptic techniques were maintained for collection of water samples for analysis of fecal-indicator bacteria, and sterile containers and equipment were used during the sampling effort. Water samples for fecal-indicator bacteria were packed in ice and transported within the 6-hour holding time to the ACHD Laboratory for analysis in accordance with the approved QAPP.

Quality Assurance

Field replicate samples were collected at a rate of 5 percent of the total number of samples collected. Laboratory replicate analyses were performed by the ACHD Laboratory. Bacteria sample bottles were tested to check for the efficiency of sterilization.

Two types of bottles were sterilized and routinely used in the analysis of fecal-indicator bacteria. During EDI sampling, 3-L sterilized bottles with sterilized caps and sterilized nozzles were fitted in the basket samplers used by the bridge team and the boat team. After shaking the 3-L bottles to mix their contents, river samples were poured from the 3-L bottles to a 250-mL polyethylene bottle that was previously sterilized. On a monthly basis, efficiency of sterilization was tested separately for the 3-L bottles and the 250-mL bottles. A certified sterile buffered water solution from the USGS Ocala Laboratory (Ocala, Fla.) was added to the 3-L bottle in the field and sent to the ACHD laboratory for analysis of FC, *E. coli*, and *enterococci*. No fecal bacteria were detected in the repeated monthly trials of this procedure; this indicates that the sterilization procedures for the 3-L bottles were effective. A similar procedure was done by pouring certified sterile buffered water into the sterilized 250-mL bottle in the field and sending the sample to the ACHD laboratory for the analysis of fecal-indicator bacteria. No fecal bacteria were detected in the repeated monthly trials of this procedure; this indicates that the sterilization procedures in use for the 250-mL bottles were effective.

Field-replicate samples were collected at the sites on the Allegheny River at Oakmont, Allegheny River at 9th Street Bridge, Monongahela River at Braddock, and Monongahela River at Pittsburgh (table 3). These field replicate samples were collected by using the water collected from an EDI sample and successively filling two 250-mL sterilized bottles after vigorously shaking the river sample collected in the 3-L sterilized EDI bottle. Even with vigorous shaking of the 3-L river sample, complete homogeneous mixing of the sample may be nearly impossible because of instantaneous settling of sediment/bacteria mixtures and clumping of bacteria to suspended organic substances. These field replicates test both the efficiency of mixing in the 3-L EDI bottle and laboratory replication efficiency. When concentrations in sample 1 and sample 2 are different (table 3), the differences may be caused by incomplete field mixing in the 3-L sample and (or) laboratory replication efficiency.

The results of the field replicate samples indicate good agreement between samples when concentrations of fecal-indicator bacteria are at the detection level (<5 col/100 mL). However, when concentrations of fecal-indicator bacteria are higher than detection levels, agreement between samples declines markedly (table 3). The largest discrepancy between samples was on August 29, 2001, when sample 1 was 2,300 col/100 mL and sample 2 was 140 col/100 mL. Additional data and side-by-side comparisons are needed to evaluate the significance of this result and identify a basis for the discrepancy between replicate samples when fecal-indicator bacteria concentrations are elevated.

Occurrence and Distribution of Fecal-Indicator Bacteria

Bacteria Concentrations and Distributions

Concentrations of *E. coli*, *enterococci*, and FC during dry-weather sampling events were greater than the WQS in 11, 28, and 28 percent of the samples, respectively; during mixed-weather events, concentrations of fecal-indicator bacteria were greater than the WQS in 28, 37, and 43 percent of the samples, respectively; and during wet-weather events, concentrations of fecal-indicator bacteria were greater than the WQS in 56, 71, and 81 percent of the samples, respectively (table 4). A summary of streamflow and water-quality data is presented in Appendix 1.

During the sample-collection period from July 12 to September 28, fecal-indicator bacteria samples were collected during dry-weather conditions on 4 days (July 24, August 7, September 4 and 18). The median concentrations for *E. coli*, *enterococci*, and FC were 30, 5, and 70 col/100 mL, respec-

Table 3. Concentrations of field replicate samples for fecal-indicator bacteria, Allegheny and Monongahela Rivers, July-September 2001.

[Fecal-indicator bacteria concentrations in colony-forming units per 100 milliliters; <, less than]

Fecal-indicator bacteria	Allegheny River at Oakmont				Allegheny River at 9th Street Bridge						Monongahela River at Braddock		Monongahela River at Pittsburgh	
	7/31/01		08/09/01		8/21/01		09/26/01		09/27/01		9/25/01		8/29/01	
	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
Escherichia coli	<5	<5	<5	<5	<5	<5	220	150	35	45	1,600	1,400	2,300	140
Enterococci	<5	<5	<5	<5	<5	<5	10	<5	5	<5	220	370	90	60
Fecal coliform	<5	<5	5	<5	<5	5	580	540	90	120	15,000	19,000	2,600	1,900

Table 4. Summary of concentrations of fecal-indicator bacteria that are above or below water-quality criteria for dry-, mixed-, and wet-weather events, July-September 2001, Allegheny County, Pennsylvania.

	Number of samples	Percentage of samples with concentrations above the water-quality standard
	Dry-weather samples[1]	
Enterococci	57	11
Escherichia coli	57	28
Fecal coliform	57	28
	Mixed-weather samples[2]	
Enterococci	75	28
Escherichia coli	75	37
Fecal coliform	75	43
	Wet-weather samples[3]	
Enterococci	129	56
Escherichia coli	129	71
Fecal coliform	129	81

[1] Includes left bank, right bank, and equal discharge-incremental sample for July 24, August 7, and September 4 and 18.

[2] Includes left bank, right bank, and equal discharge-incremental sample for July 12, 18, and 31, and August 14 and 21.

[3] Includes left bank, right bank, and equal discharge-incremental sample for August 8-10, August 28-30, and September 25-28.

Table 5. Summary statistics for streamflow, temperature, and concentrations of fecal-indicator bacteria for the five sampling sites within the Three Rivers region, Pa., July-September 2001.

[min, minimum; max, maximum; <, less than]

	Streamflow, in cubic feet per second	Temperature, in degrees Celsius	*Escherichia coli,* in colonies per 100 milliliters	*Enterococci*, in colonies per 100 milliliters	Fecal coliform, in colonies per 100 milliliters
			Allegheny River at Oakmont		
Min:	2,810	20	<5	<5	<5
Median:	4,040	29	28	5	50
Max:	5,650	35	820	690	960
			Allegheny River at 9th Street Bridge		
Min:	3,140	19.5	3	<5	<5
Median:	4,220	27	140	15	280
Max:	5,910	30	7,900	575	21,000
			Monongahela River at Braddock		
Min:	2,350	19.5	<5	<5	<5
Median:	5,400	26.5	280	30	520
Max:	21,800	29.0	12,000	630	23,000
			Monongahela River at Pittsburgh		
Min:	2,700	21	5	<5	10
Median:	5,270	26	260	25	620
Max:	19,900	30	39,000	1,060	50,000
			Ohio River at Sewickley		
Min:	6,480	17.5	<5	<5	8
Median:	11,400	27	220	20	245
Max:	26,300	32	3,100	705	31,000

tively. These median concentrations were below the WQS. During mixed-weather events, the median concentra-tions also were below the WQS; median concentrations of *E. coli*, *enterococci*, and FC were 50, 2.5, and 80, respectively. Median concentrations exceeded the WQS only during wet weather. The median concentration of *E. coli* (410 col/100 mL) for wet-weather samples exceeded the WQS of 126 col/100 mL. The median concentration of FC (695 col/100 mL) for wet-weather samples exceeded the WQS of 200 col/100 mL.

Summary statistics for streamflow, temperature, and concentrations of fecal-indicator bacteria for the five sampling sites within the Three Rivers for July through September are provided in table 5. The lowest median concentrations for *E. coli*, *enterococci*, and FC were measured at the Allegheny River at Oakmont. Median concentrations for fecal-indicator bacteria for the four other sites were similar to each other. Median concentrations at these sites were roughly 5 to 10 times greater than that at the Allegheny River at Oakmont.

Wet-weather concentrations exceeded those reported during dry-weather events for all sites, except the Allegheny River at Oakmont (figs. 5, 6, and 7). This may be a function of dilution during wet-weather events or the lack of upgradient source streams. Additionally, concentrations of *E. coli* and FC frequently exceeded the WQS reported during wet-weather events. For dry-weather conditions, only three sample events (July 24, September 4, 18) met the 72-hour antecedent condition of no rainfall. As a result, comparing data between sites should be done with caution. Additional data would be needed to develop more definitive relations between sites.

Weather Effects

Establishing a trend in concentrations of fecal-indicator bacteria as a function of time after a wet-weather event carries a measure of uncertainty because of a variety of factors including the spatial variability of sources contributing fecal material, dry-weather discharges, resuspension of bottom sediments, and flow augmentation from the U.S. Army Corps of Engineer (USACE) reservoirs. However, FC concentrations appear to decrease with time compared to the other fecal-indicator bacteria. This decrease may be attributed to the greater rate of die-off, which is consistent with FC bacteria. A summary of wet-weather data from composite samples collected at each sample location is presented in table 6.

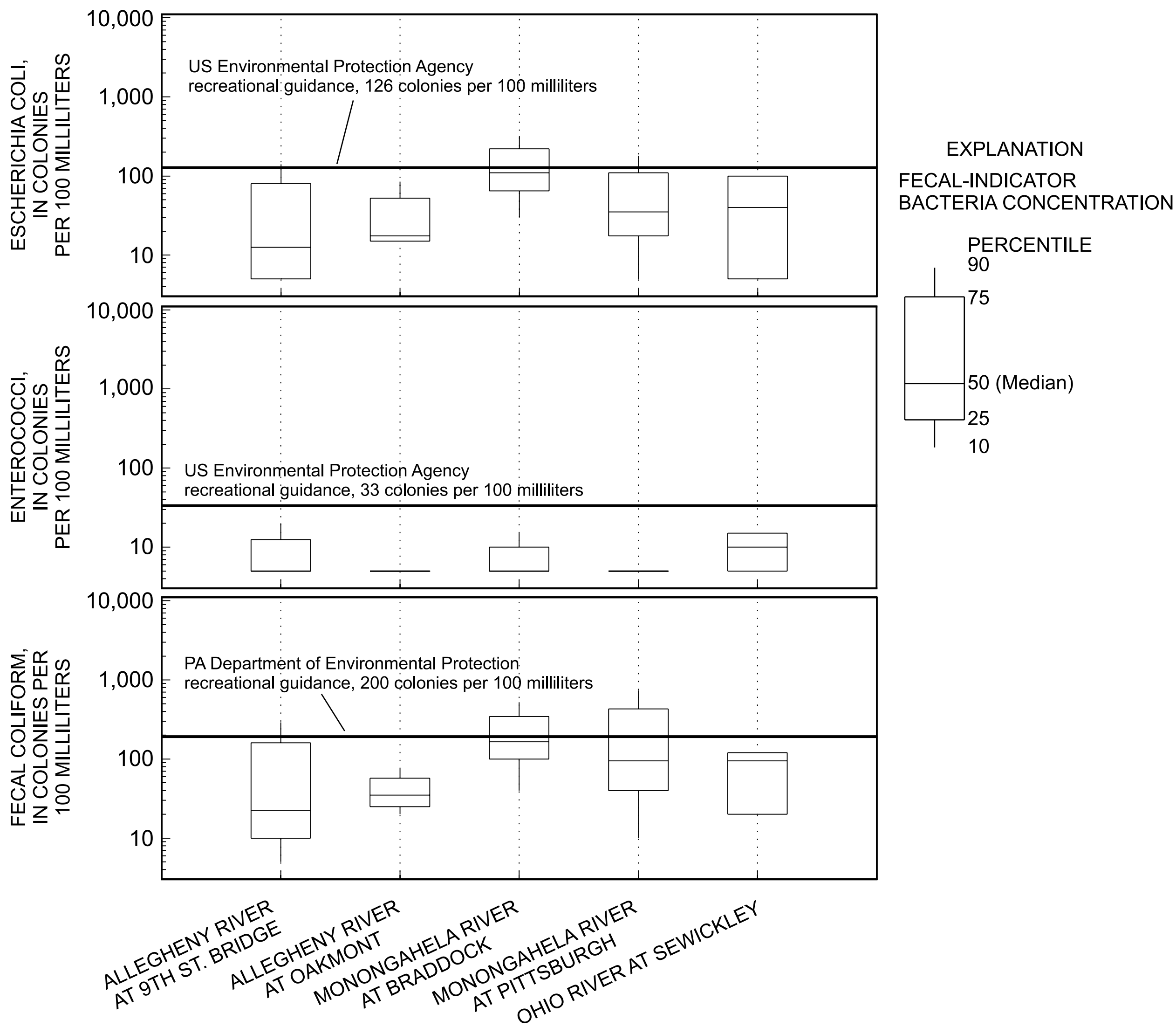


Figure 5. Fecal-indicator bacteria colonies in composite samples collected on the Allegheny, Monongahela, and Ohio Rivers near Pittsburgh, Pa., during dry weather, 2001.

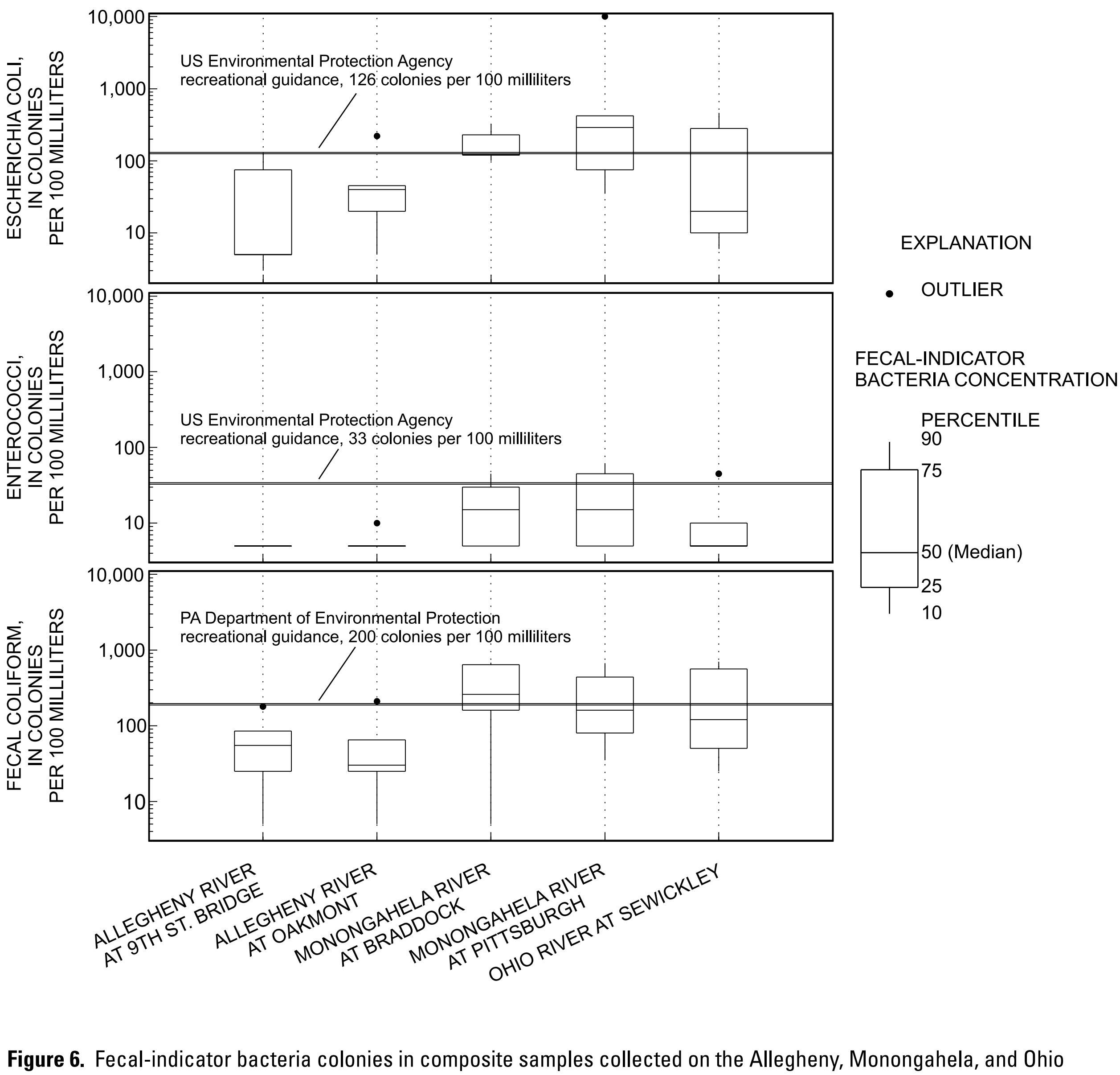


Figure 6. Fecal-indicator bacteria colonies in composite samples collected on the Allegheny, Monongahela, and Ohio Rivers near Pittsburgh, Pa., during mixed weather, 2001.

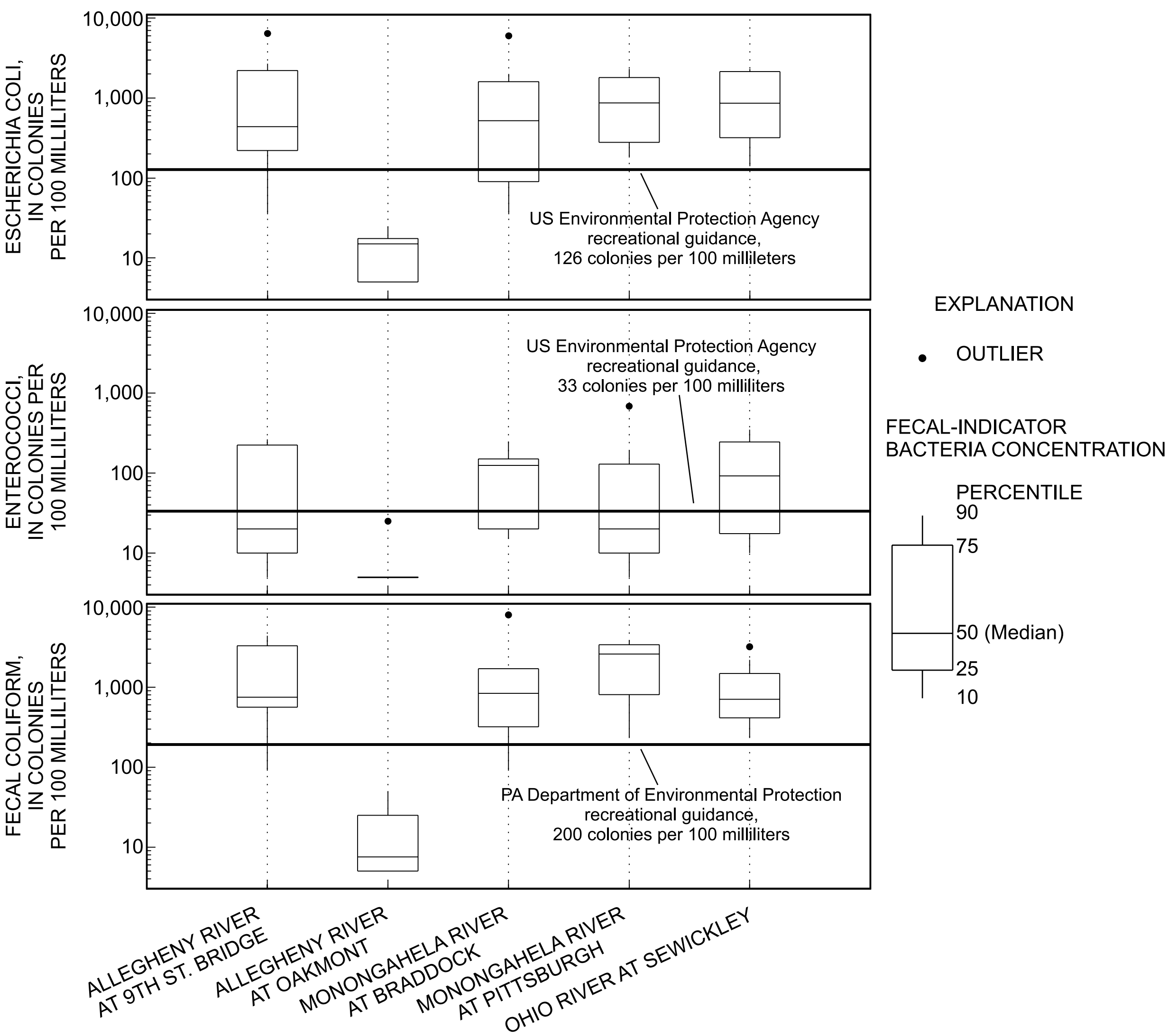


Figure 7. Fecal-indicator bacteria colonies in composite samples collected on the Allegheny, Monongahela, and Ohio Rivers near Pittsburgh, Pa., during wet weather, 2001.

Table 6. Concentrations of fecal-indicator bacteria in composite samples collected during wet-weather events, Allegheny, Monongahela, and Ohio Rivers near Pittsburgh, Pennsylvania, August-September 2001.

[ns, no sample]

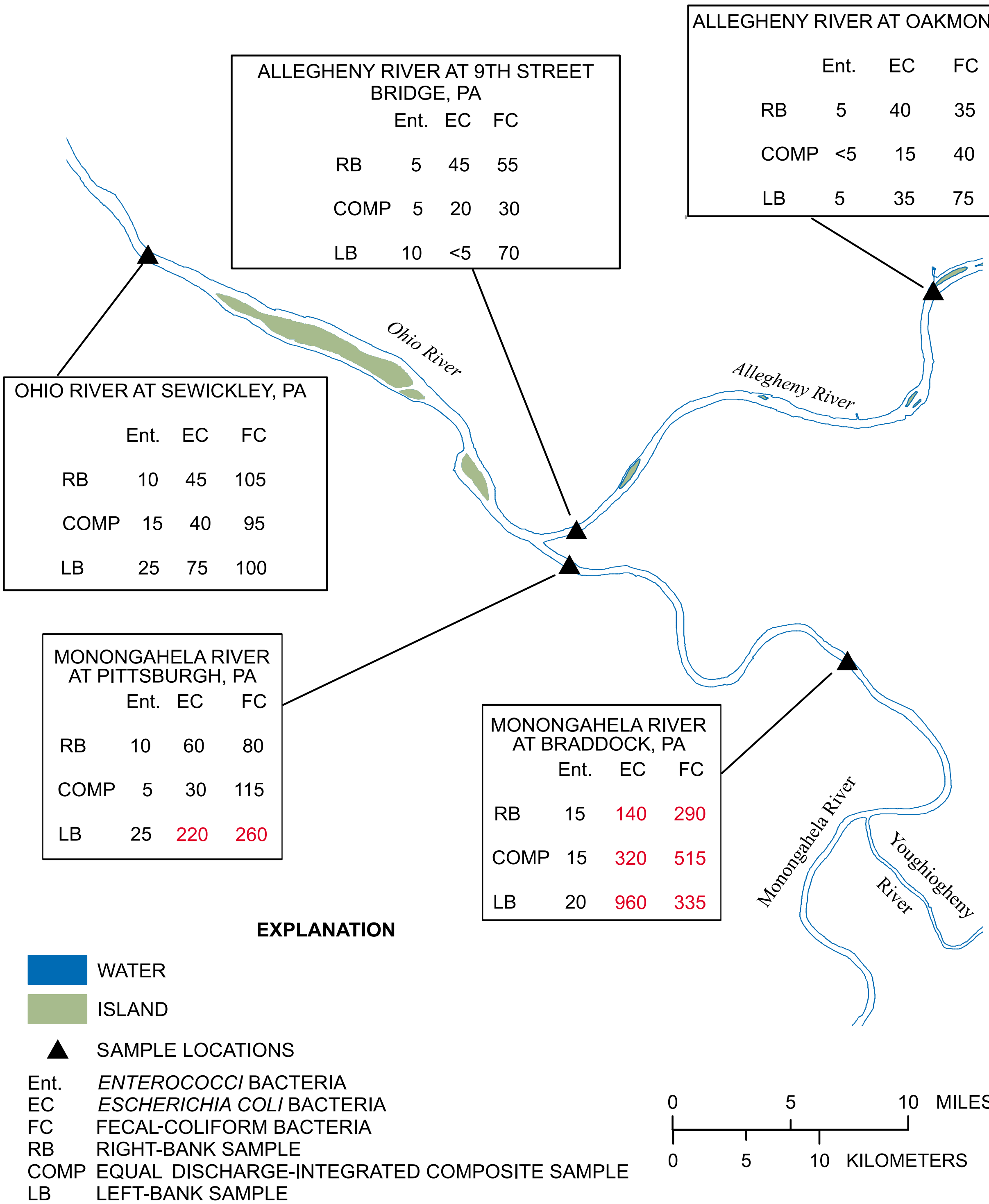
Site name	Sampling date									
	August			August			September			
	8	9	10	28	29	30	25	26	27	28
***Escherichia coli*, in colonies per 100 milliliters**										
Ohio River at Sewickley	1,300	400	420	240	2,300	2,300	ns	2,000	ns	140
Monongahela River at Braddock	6,000	35	510	520	2,000	50	1,600	90	570	ns
Allegheny River at Oakmont	2.5	2.5	2.5	25	2.5	15	15	ns	15	ns
Allegheny River at 9th Street Bridge	2,700	440	6,400	420	2,200	35	690	220	35	ns
Monongahela River at Pittsburgh	1,800	180	2,000	280	2,300	260	960	870	500	ns
***Enterococci*, in colonies per 100 milliliters**										
Ohio River at Sewickley	350	115	70	10	310	180	ns	20	ns	15
Monongahela River at Braddock	125	20	15	130	250	150	220	15	135	ns
Allegheny River at Oakmont	2.5	2.5	2.5	25	2.5	25	2.5	ns	2.5	ns
Allegheny River at 9th Street Bridge	230	20	225	20	265	100	5.0	2.5	5.0	ns
Monongahela River at Pittsburgh	130	15	195	20	90	685	2.5	5.0	10	ns
Fecal coliform, in colonies per 100 milliliters										
Ohio River at Sewickley	650	580	250	760	2,200	770	ns	3,200	ns	230
Monongahela River at Braddock	8,000	90	840	1,500	1,700	740	15,000	250	320	ns
Allegheny River at Oakmont	2.5	5.0	35	50	5	10	5	ns	15	ns
Allegheny River at 9th Street Bridge	4,400	560	14,000	750	3,300	540	880	580	90	ns
Monongahela River at Pittsburgh	3,500	3,400	2,800	650	2,600	3,900	810	880	230	ns

Routine sampling for fecal-indicator bacteria began on July 12 and extended to September 28. In general, dry-weather or mixed-weather samples were collected weekly at each section. Three wet-weather events also were sampled. On August 8, August 28, and September 24, approximately 1.39, 1.87, and 0.85 in. of precipitation, respectively, were recorded at the Pittsburgh International Airport rain gage operated by the National Weather Service (NWS). At a network of 21 precipitation gages in Allegheny County, median precipitation quantities for August 8, August 28, and September 24 were 0.39, 1.11, and 0.77 in., respectively. In addition, samples were collected on selected days after precipitation ended in an effort to establish the period of time needed for bacteria concentrations to decline to below the WQS.

Concentrations of fecal-indicator bacteria for the five sites on the Three Rivers sampled during dry weather on August 7 are presented in figure 8. No precipitation was measured on August 4, 5, and 6, and during the day of sampling on August 7; therefore, the event complied with the definition of dry weather established by ORSANCO. The concentrations of *enterococci*, *E. coli*, and FC were below the WQS on August 7 for bank and composite samples at the following sites: Allegheny River at Oakmont, Allegheny River at 9th St. Bridge, and Ohio River at Sewickley. Concentrations of FC and *E. coli* at the Monongahela River at Braddock were slightly above the WQS, and the *enterococci* concentrations were below the WQS. The cause(s) of the elevated concentrations of *E. coli* and FC during dry weather are unknown, but possible sources may include sewage discharging from tributary streams upstream of the site, waterfowl, malfunctioning sewage-treatment plants or overflows, leaking sewer lines, marinas, malfunctioning onlot sewage systems, and agricultural runoff.

On August 8, 2001, heavy rains fell on part of Allegheny County from approximately 2 a.m. to 6 a.m. The long-term rain gage at Pittsburgh International Airport recorded 1.39 in., a record for August 8. Nine rain gages in the NWS network in Allegheny County recorded from 0.04 to 1.55 in.; the median precipitation for these gages was 0.44 in. The rain was concentrated mostly in Allegheny County; the median rainfall quantities from the NWS county networks in the adjacent counties of Armstrong, Butler, Washington, and Westmoreland were all zero. This rainfall event for Allegheny County met the criteria for wet weather as defined by ORSANCO (a 48-hour dry antecedent period and at least 0.3 in. of precipitation in a 6-hour period).

Concentrations of fecal-indicator bacteria were above the WQS for composite and bank samples collected on August 8 at the following sites: Allegheny River at 9th St. Bridge, Monongahela River at Braddock, Monongahela River at Pittsburgh, and Ohio River at Sewickley (fig. 9). At the site at Allegheny



EXPLANATION

WATER

ISLAND

SAMPLE LOCATIONS

Ent. *ENTEROCOCCI* BACTERIA
EC *ESCHERICHIA COLI* BACTERIA
FC FECAL-COLIFORM BACTERIA
RB RIGHT-BANK SAMPLE
COMP EQUAL DISCHARGE-INTEGRATED COMPOSITE SAMPLE
LB LEFT-BANK SAMPLE
< LESS THAN

BACTERIA CONCENTRATIONS ARE EXPRESSED AS THE NUMBER OF COLONIES PER 100 MILLILITERS OF SAMPLE. CONCENTRATIONS IN RED EXCEED WATER-QUALITY STANDARDS.

Figure 8. Concentrations of fecal-indicator bacteria during dry weather on August 7, 2001, from five sites on the Allegheny, Monongahela, and Ohio Rivers near Pittsburgh, Pennsylvania.

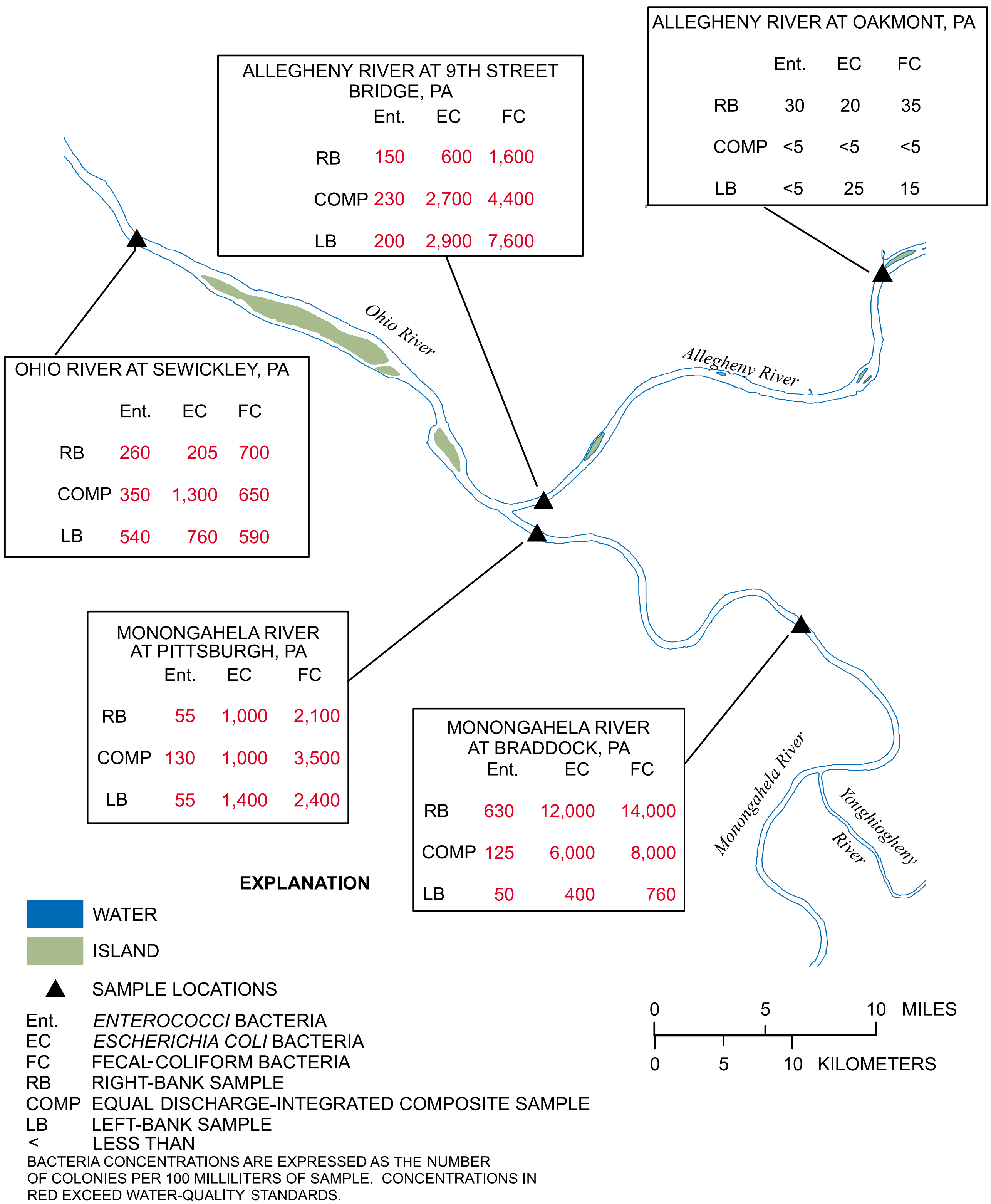


Figure 9. Concentrations of fecal-indicator bacteria after wet weather on August 8, 2001, from five sites on the Allegheny, Monongahela, and Ohio Rivers near Pittsburgh, Pennsylvania.

River at 9th St. Bridge and the Ohio River at Sewickley site, the wet-weather effects on the bacteria concentrations resulted in all samples exceeding the WQS on August 8; concentrations were below the WQS the previous day (fig. 8). The Allegheny River at Oakmont was on the periphery of the storm on August 8, resulting in reduced runoff rates compared to stations in areas receiving larger rainfall amounts. The pattern of composite samples of the three indicator bacteria below the WQS for several days after wet-weather events also was observed during the other two wet-weather events on August 28-30 and September 25-27. A hypothesis that could be tested in future wet-weather sampling would be to examine if the daily discharges suspected of containing few bacteria from many USACE reservoirs upstream of the Allegheny River at Oakmont act to dilute the loads of bacteria discharging to the Allegheny River upstream of Oakmont during wet weather. Bacteria source streams, entering the Allegheny River between Oakmont and 9th St. Bridge during the wet-weather event of August 8, resulted in all nine samples for all three indicator bacteria being above the WQS for the August 8 samples collected from the Allegheny River at 9th St. Bridge. This supports the findings that a source(s) of bacterial contamination exists between the Oakmont and 9th St. Bridge sites.

The bacteria concentrations reported in some of the bank samples collected at each site were greater than in the composite sample. This is attributed in part to incomplete mixing of source streams adjacent to the river banks. Depending on the difference in the momentum between the source and the receiving water, the discharges may be strongly deflected and have a tendency to hug the side of the receiving water channel. This is particularly true within the near-field mixing region, where the jet characteristics of the discharge (momentum, buoyancy, and outfall geometry) dominate. As the plume travels downstream, these characteristics become less important, and the characteristics of the receiving water (momentum, velocity distribution, channel geometry, buoyant spreading, and diffusion) dominate the mixing process. The point at which mixing becomes more uniform is based on the distribution of additional point discharges downstream and the hydrodynamics of the receiving water. In the event conditions are well-mixed, peak concentrations would be expected to coincide with that part of a channel where the maximum velocity occurs.

Monongahela River Subbasins

During the sampling period, the greatest median concentrations of *E. coli* (280 col/100 mL, 260 col/100 mL) and *enterococci* (30 col/100 mL, 25 col/100 mL) bacteria were reported at Monongahela River at Braddock and Monongahela River at Pittsburgh, respectively (table 4). Maximum concentrations of *E. coli*, *enterococci*, and FC were 12,000; 630; and 23,000 col/100 mL, respectively, for the Monongahela River at Braddock. The elevated concentrations along the Monongahela River compared to the other rivers may be attributed to a number of variables, including the predominant land use within the subbasins, the distribution of CSOs/SSOs, high streamflows, and resuspension of sediments.

The land use within the study area is shown in figure 10. The percent urban land cover for the Monongahela River subbasins is greater than or equal to that reported for the Allegheny and Ohio Rivers. The Monongahela River subbasins include the area drained by the Monongahela River and its tributaries within the border of Allegheny County. As previously indicated, areas dominated by urban and suburban basins may generate fecal-indicator bacteria. Stormwater runoff, which can contain coliform concentrations consistent with those reported in WWTP effluent (U.S. Environmental Protection Agency, 2001), in impervious areas can quickly transport fecal matter from litter, pets, and wildlife.

Additionally, the number of CSOs and SSOs per square mile is greater for the Monongahela River subbasins than that reported for the Allegheny River (fig. 11). The relative contributions of fecal material from these discharges could explain the elevated bacteria concentrations reported at the Monongahela River sampling sites.

Resuspension of sediment within large river systems may contribute fecal matter to the water column. Recreational and commercial boat traffic or high streamflow within the Monongahela River subbasins may contribute to resuspended sediment within the channel. This is supported in part by the velocity distribution shown in figure 3, which suggests that effects such as barge propeller wash cause vertical flow components that extend to the channel bottom 15 ft below the water surface. During a routine sampling event, the ADCP streamflow measurement was interrupted by intermittent barge traffic. Typically, four transects are performed, and the discharge rate is then established using the mean of the four measurements. After two transects, the measurement was temporarily discontinued until the traffic passed. However, during subsequent transects, it was evident that velocity distribution was altered significantly by the propeller wash associated with the barge. However, whether the sediment contains fecal matter has not been confirmed.

To evaluate the significance of the concentrations of fecal-indicator bacteria and turbidity reported in grab and composite samples during dry-, mixed-, and wet-weather events, data sets were evaluated using Wilcoxon rank sum tests. Tests were conducted using each of the fecal-indicator bacteria by site and by weather event. For example, concentrations of FC reported in the left-bank sample were compared to the right-bank and composite samples for the Ohio River at Sewickley site during dry, mixed, and wet events.

The Wilcoxon rank sum test is a nonparametric test used to evaluate independent data sets for one sample, two samples, and paired samples. It tests the shift in location between the populations (i.e. the measurements from one population are either greater or less than those from the other population). The Wilcoxon rank sum test offers the following two advantages over other test statistics such as the independent t-test, including (1) data sets are not forced to fit a normal distribution, and

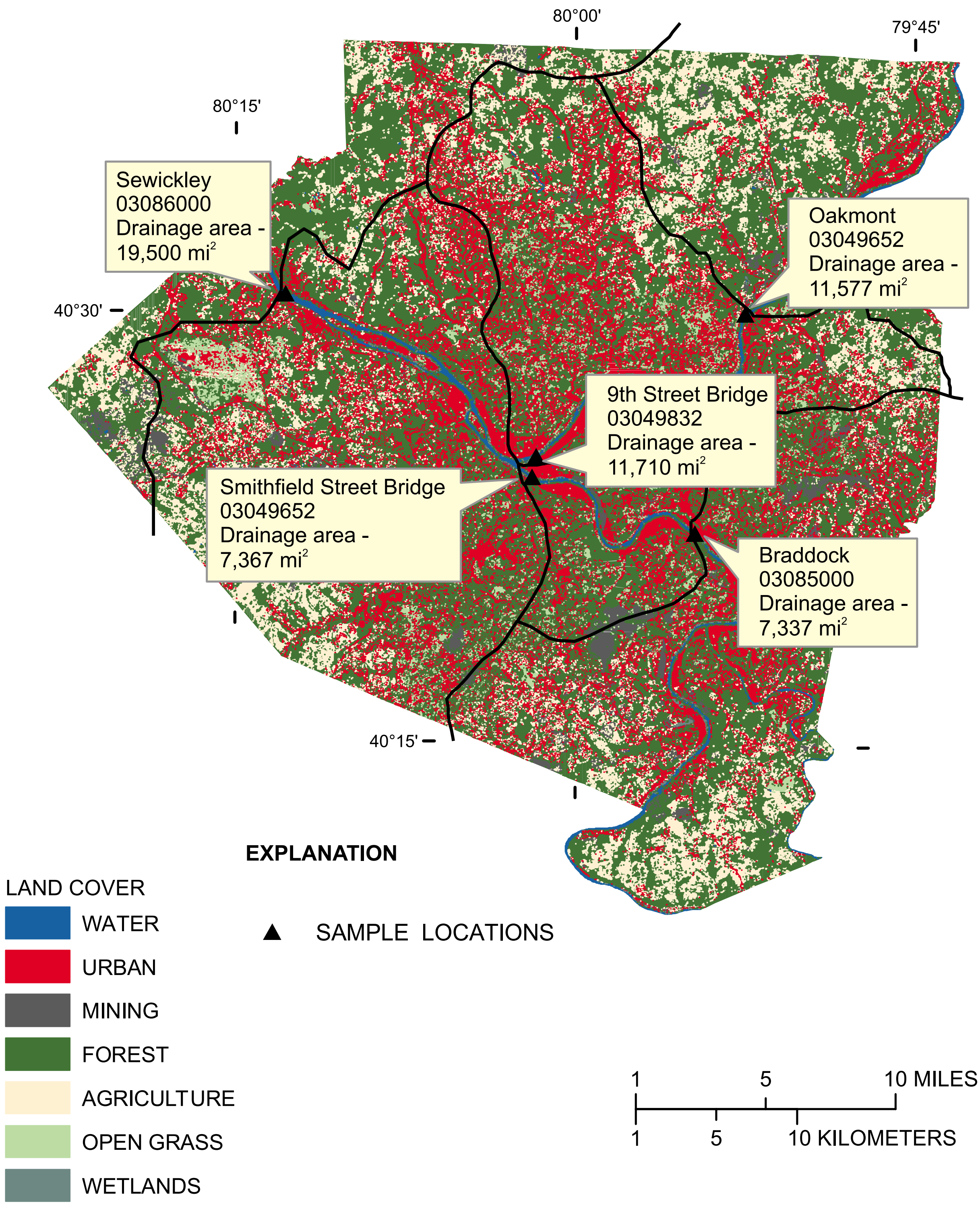


Figure 10. Land cover of five subbasins within the Allegheny, Monongahela, and Ohio Rivers region, Allegheny County, Pennsylvania.

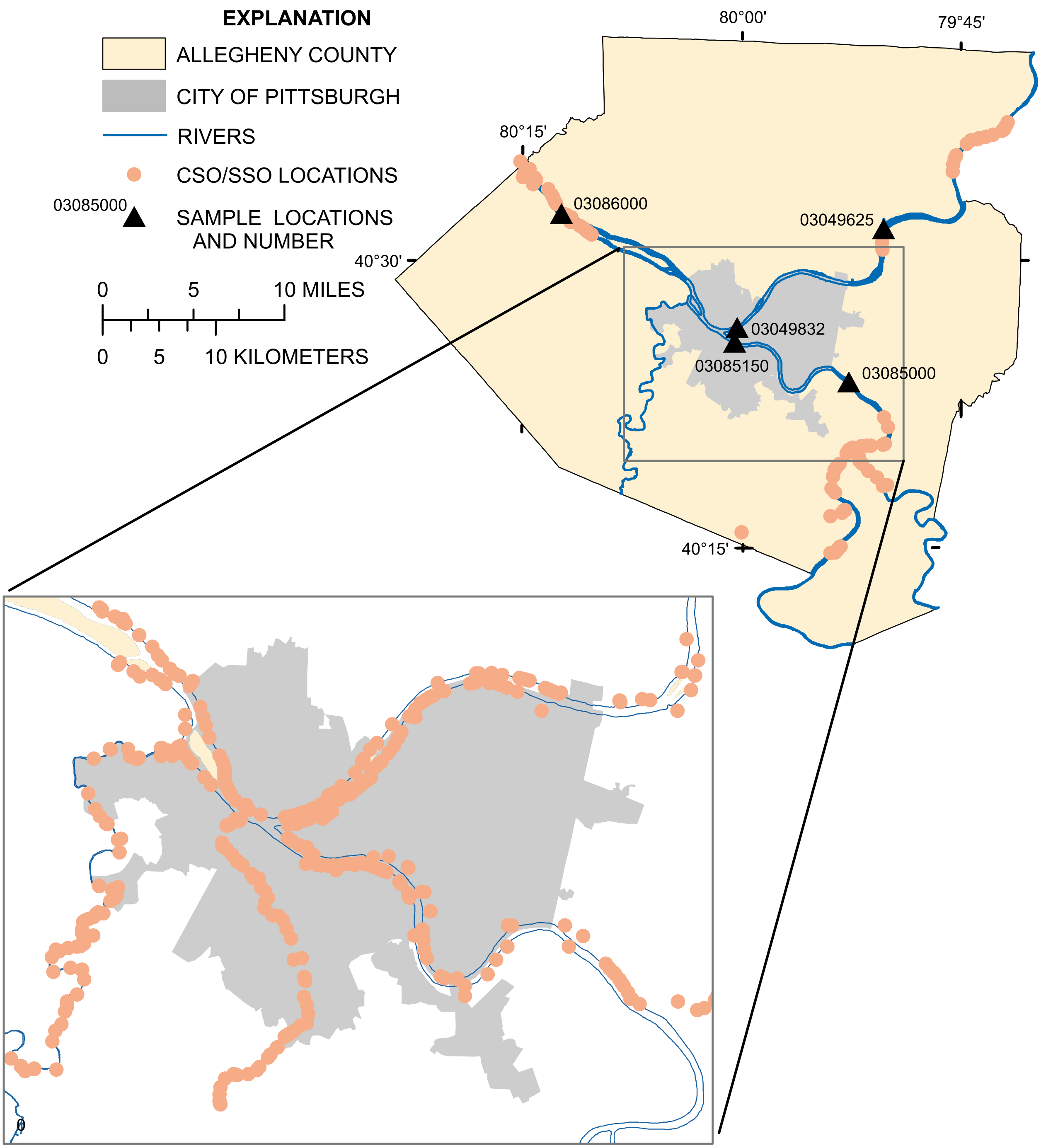


Figure 11. Distribution of combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) near Pittsburgh, Pennsylvania.

(2) ranking can be incorporated into the analysis. The results of the analysis are presented in table 7.

For the Monongahela River at Braddock, no statistically significant relations were observed for the three fecal-indicator bacteria for these three comparisons: 1) right-bank grab sample to composite sample, 2) left-bank grab sample to composite sample, and 3) right-bank grab sample to left-bank grab sample (table 7). For dry-weather samples for the Monongahela River at Pittsburgh, two statistically significant relations were observed for *enterococci*: 1) right-bank grab samples were different than composite samples and 2) left-bank samples were different than composite samples. For the Monongahela River at Braddock, four of nine turbidity comparisons were statistically significant (table 7). For the Monongahela River at Pittsburgh, three of nine turbidity comparisons were statistically significant.

Additional data sets are needed to adequately assess the significance of the distribution of bacteria at a given station. This is particularly true for wet-weather events; where days 1, 2, and 3 after a storm were evaluated collectively. For example, with the inclusion of additional data; right bank, wet weather-day 1 samples for the Ohio River at Sewickley can be compared to the composite, wet weather-day 1 sample for the same station. The existence of lack of significance may be influenced by factors such as bacteria die-off rates and supplemental source streams.

Allegheny River Subbasins

Flow augmentation associated with upstream reservoirs operated and maintained by the USACE along the Allegheny River may provide some degree of dilution for fecal loads discharged to the river. Depending on the time of year, these reservoirs can provide as much as 25 percent of the flow reported at the streamflow-measurement station on the Allegheny River at Natrona, 11.6 mi upstream of the Allegheny River at Oakmont. Additionally, the number of CSOs and SSOs upstream of Oakmont on the border of Allegheny County are limited to about 12. Therefore, the contribution of these point-source discharges may be small compared to the number of source streams on the Monongahela River. This is supported by the median concentrations of *E. coli* (28 col/100 mL) and enterococci (5 col/100 mL) (table 5). Maximum concentrations of *E. coli*, *enterococci*, and FC were 820, 690, and 960 col/100 mL, respectively, for the Allegheny River at Oakmont.

Concentrations of fecal-indicator bacteria at the sampling site on the Allegheny River at 9th St. Bridge are greater than those reported at Oakmont. The median concentrations of *E. coli* (140 col/100 mL) and *enterococci* (15 col/100 mL) reported during the sampling period are shown in table 5. Maximum concentrations of *E. coli*, *enterococci*, and FC were 7,900; 575; and 21,000 col/100 mL, respectively (table 5). The increase appears to be attributed to the high number of CSOs and SSOs between 9th St. Bridge and Oakmont and the change in land use close to the mouth of the Allegheny River.

For the Allegheny River at Oakmont (table 7), six statistically significant relations were observed for wet-weather samples for the three fecal-indicator bacteria. Comparison of the concentrations in bank samples and composite samples (Appendix 1) indicates that the bank-sample concentrations generally were larger than the composite samples. Only one statistically significant relation for Oakmont was observed for dry weather. For *E. coli*, left-bank grab samples were different from composite samples for dry-weather samples. A statistically significant p-value of 0.04 indicated that left-bank grab samples were different from composite samples for *enterococci* concentrations for mixed weather at Oakmont. No statistically significant relations were observed for turbidity for the Allegheny River at Oakmont (table 7).

For the sampling site on the Allegheny River at 9th St. Bridge, two significant relations were observed for *enterococci* in mixed-weather samples: 1) right-bank samples were different from composite samples, and 2) right-bank samples were different from left-bank samples. For this sampling site, five of nine relations for turbidity were significant (table 7).

Ohio River Subbasins

Concentrations of fecal-indicator bacteria at the Ohio River at Sewickley, in part, represent the combined flows of the Allegheny and Monongahela Rivers and additional point and nonpoint discharges downstream of the Ohio River confluence. Median concentrations of *E. coli* (220 col/100 mL) and *enterococci* (20 col/100 mL) are similar to those reported at the Allegheny River at 9th St. Bridge, the Monongahela River at Braddock, and the Monongahela River at Pittsburgh. Maximum concentrations of *E. coli*, *enterococci*, and FC were 3,100; 705; and 31,000 col/100 mL, respectively (table 5).

One significant relation (p-value = 0.04) was observed for *E. coli* during wet-weather events in left-bank compared to composite samples. A statistically significant comparison (p-value = 0.081) of right-bank compared to left-bank samples during dry weather was observed for *enterococci*. Similar observations were noted for turbidity; two statistically significant relations were observed: 1) dry-weather right-bank samples had different turbidity readings than dry-weather composite samples, and 2) mixed-weather right-bank samples had different turbidity readings than composite samples.

Comparison to Water-Quality Standards

Comparisons of WQS for concentrations of *E. coli*, *enterococci*, and FC for wet- and dry-weather samples are provided in figures 5, 6, and 7, respectively. For wet-weather samples for *enterococci*, 56 percent of samples exceeded the USEPA criterion of 33 col/100 mL. For *E. coli*, 71 percent of samples for wet weather exceeded the USEPA criterion of 33 col/100 mL. A total of 81 percent of samples exceeded the PaDEP criterion for wet weather for FC bacteria samples (table 4).

Table 7. Statistically significant relations for fecal-indicator bacteria for dry-, mixed-, and wet-weather samples, July-September 2001, Allegheny Co unty, Pa.

[ns, p-value greater than 0.10 and is not significant; RB, right-bank sample; LB, left-bank sample; Comp, composite sample]

Water-quality parameter and comparison tested	Allegheny River						Monongahela River						Ohio River		
	Oakmont			9th St. Bridge			Braddock			Pittsburgh			Sewickley		
	Wet	Dry	Mixed	Wet	Dry	Mixed	Wet	Dry	Mixed	Wet	Dry	Mixed	Wet	Dry	Mixed
Escherichia coli															
RB – Comp	0.006	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
LB – Comp	.005	0.1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0.04	ns	ns
RB – LB	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Enterococci															
RB – Comp	.02	ns	ns	ns	ns	0.007	ns	ns	ns	ns	0.07	ns	ns	ns	ns
LB – Comp	.05	ns	0.04	ns	ns	ns	ns	ns	ns	ns	.02	ns	ns	ns	ns
RB – LB	ns	ns	ns	ns	ns	.08	ns	ns	ns	ns	ns	ns	ns	0.08	ns
Fecal coliform															
RB – Comp	.006	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
LB – Comp	.003	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
RB – LB	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Turbidity															
RB – Comp	ns	ns	ns	0.03	ns	.04	0.08	0.03	ns	0.003	ns	ns	ns	.08	0.06
LB – Comp	ns	ns	ns	.04	0.03	.1	ns	.05	ns	.04	.03	ns	ns	ns	ns
RB – LB	ns	ns	ns	ns	ns	ns	ns	.04	ns	ns	ns	ns	ns	ns	ns

Several dry-weather exceedences for *E. coli* and FC were reported in the Allegheny and Monongahela Rivers. The source stream contributing to the load is unknown. Wet-weather exceedences were more frequent and were isolated primarily to the lower reaches of the Allegheny River, the Monongahela, and Ohio Rivers. Concentrations of three indicator bacteria were less than the established recreational WQS at Oakmont.

Load Estimates

A convenient way to represent the magnitude of bacteria in a receiving water is to multiply a concentration by the discharge rate, which is characteristic of the cross section at the time of sampling. This magnitude is a measure of the bacteria load within the receiving water. The USEPA (2001) has developed a protocol for determining the total maximum daily load (TMDL) of pathogens such as the fecal-indicator bacteria discussed in this report.

A TMDL can be used as a tool for implementing state WQS and is based on the relation between the source of a pollutant (pathogen) and the assimilative capacity of the receiving water. Ultimately, the TMDL can be used to establish an allowable load for a given pathogen in a water body without exceeding applicable WQS. The information presented in this report may be helpful to water-resources managers in development of TMDLs for the Three Rivers region.

Estimated fecal-indicator bacteria loads were established for each site and are presented in table 8. Loads were calculated by multiplying the EDI composite concentration by the streamflow measured during the day of sampling and are based on the following equation:

$$Load_{fecal\text{-}indicator\ bacteria}\frac{colonies}{day} = Q\frac{ft^3}{s}\cdot\frac{Bacteria\ colonies}{100mL}\cdot\frac{mL}{0.001\ L}\cdot\frac{28.3\ L}{1\,ft^3}\cdot\frac{60\ s}{min}\cdot\frac{60\ min}{hr}\cdot\frac{24\ hr}{day} \tag{1}$$

Significant increases in loads were observed from Oakmont, the upstream boundary of the study area, to the 9th Street Bridge, at the confluence of the Allegheny and Ohio Rivers. This observation was consistent for each of the storms sampled. The loads established for Sewickley reflect the contribution from the Monongahela subbasin and source streams along the Ohio River. Additionally, loads decreased significantly during days 2, 3, and 4 after storm cessation.

Table 8. Estimated daily loads of fecal-indicator bacteria within the Allegheny, Monongahela, and Ohio Rivers near Pittsburgh, Pennsylvania, July-September 2001

U.S. Geological Survey station number	Site name	Event	Date	Streamflow, in cubic feet per second	*Escherichia coli*, in colonies per 100 milliliter	*Escherichia coli* load, in colonies per day	*Enterococci*, in colonies per 100 milliliters	*Enterococci* load, in colonies per day	Fecal coliform, in colonies per 100 milliliters	Fecal coliform load, in colonies per day
03049652	Oakmont	Dry	07/24/01	4,040	15	1.E+12	<5	5.E+11	30	3.E+12
03049652	Oakmont	Dry	08/07/01	5,650	15	2.E+12	<5	7.E+11	40	6.E+12
03049652	Oakmont	Dry	09/04/01	3,980	85	8.E+12	<5	5.E+11	75	7.E+12
03049652	Oakmont	Dry	09/18/01	3,630	20	2.E+12	<5	4.E+11	20	2.E+12
03049832	9th St. Bridge	Dry	07/24/01	5,910	140	2.E+13	20	3.E+12	290	4.E+13
03049832	9th St. Bridge	Dry	08/07/01	4,960	20	2.E+12	5	6.E+11	30	4.E+12
03049832	9th St. Bridge	Dry	09/04/01	4,220	<5	5.E+11	<5	5.E+11	15	2.E+12
03049832	9th St. Bridge	Dry	09/18/01	3,320	5	4.E+11	<5	4.E+11	5	4.E+11
03085000	Braddock	Dry	09/18/01	2,350	30	2.E+12	5	3.E+11	40	2.E+12
03085000	Braddock	Dry	07/24/01	3,180	120	9.E+12	5	4.E+11	170	1.E+13
03085000	Braddock	Dry	08/07/01	4,720	320	4.E+13	15	2.E+12	520	6.E+13
03085000	Braddock	Dry	09/04/01	5,120	100	1.E+13	5	6.E+11	160	2.E+13
03085150	Smithfield St. Bridge	Dry	07/24/01	3,180	40	3.E+12	<5	4.E+11	70	5.E+12
03085150	Smithfield St. Bridge	Dry	08/07/01	5,060	30	4.E+12	5	6.E+11	120	1.E+13
03085150	Smithfield St. Bridge	Dry	09/04/01	5,800	180	3.E+13	<5	7.E+11	740	1.E+14
03085150	Smithfield St. Bridge	Dry	09/18/01	2,700	5	3.E+11	5	3.E+11	10	7.E+11
03086000	Sewickley	Dry	07/24/01	8,300	<5	1.E+12	10	2.E+12	20	4.E+12
03086000	Sewickley	Dry	08/07/01	11,400	40	1.E+13	15	4.E+12	95	3.E+13
03086000	Sewickley	Dry	09/04/01	9,600	100	2.E+13	<5	1.E+12	120	3.E+13
03049652	Oakmont	Mixed	07/12/01	4,360	220	2.E+13	5	5.E+11	210	2.E+13
03049652	Oakmont	Mixed	07/18/01	4,150	40	4.E+12	<5	5.E+11	25	3.E+12
03049652	Oakmont	Mixed	07/31/01	4,040	<5	5.E+11	<5	5.E+11	<5	5.E+11
03049652	Oakmont	Mixed	08/14/01	3,410	45	4.E+12	<5	4.E+11	65	5.E+12
03049652	Oakmont	Mixed	08/21/01	2,810	20	1.E+12	10	7.E+11	30	2.E+12
03049832	9th St. Bridge	Mixed	07/12/01	4,130	130	1.E+13	<5	5.E+11	180	2.E+13
03049832	9th St. Bridge	Mixed	07/18/01	4,080	3	3.E+11	5	5.E+11	55	5.E+12
03049832	9th St. Bridge	Mixed	07/31/01	3,530	5	4.E+11	<5	4.E+11	25	2.E+12
03049832	9th St. Bridge	Mixed	08/14/01	4,230	75	8.E+12	<5	5.E+11	<85	9.E+12
03049832	9th St. Bridge	Mixed	08/21/01	3,140	<5	4.E+11	<5	4.E+11	<5	4.E+11
03085000	Braddock	Mixed	07/12/01	14,800	<100	4.E+13	<5	2.E+12	5	2.E+12
03085000	Braddock	Mixed	07/18/01	3,670	120	1.E+13	<5	4.E+11	160	1.E+13
03085000	Braddock	Mixed	07/31/01	21,800	120	6.E+13	30	2.E+13	260	1.E+14
03085000	Braddock	Mixed	08/14/01	11,600	230	7.E+13	15	4.E+12	680	2.E+14
03085000	Braddock	Mixed	08/21/01	3,340	320	3.E+13	45	4.E+12	640	5.E+13

Table 8. Estimated daily loads of fecal-indicator bacteria within the Allegheny, Monongahela, and Ohio Rivers near Pittsburgh, Pennsylvania, July-September 2001 —Continued.

U.S. Geological Survey station number	Site name	Event	Date	Streamflow, in cubic feet per second	*Escherichia coli*, in colonies per 100 milliliter	*Escherichia coli* load, in colonies per day	*Enterococci*, in colonies per 100 milliliters	*Enterococci* load, in colonies per day	Fecal coliform, in colonies per 100 milliliters	Fecal coliform load, in colonies per day
03085150	Smithfield St. Bridge	Mixed	07/12/01	14,000	290	1.E+14	60	2.E+13	440	2.E+14
03085150	Smithfield St. Bridge	Mixed	07/18/01	3,080	35	3.E+12	<5	4.E+11	35	3.E+12
03085150	Smithfield St. Bridge	Mixed	07/31/01	19,900	10,000	5.E+15	15	7.E+12	160	8.E+13
03085150	Smithfield St. Bridge	Mixed	08/14/01	10,700	75	2.E+13	<5	1.E+12	80	2.E+13
03085150	Smithfield St. Bridge	Mixed	08/21/01	3,030	420	3.E+13	45	3.E+12	670	5.E+13
03086000	Sewickley	Mixed	07/12/01	22,600	280	2.E+14	45	2.E+13	700	4.E+14
03086000	Sewickley	Mixed	07/18/01	8,200	6	1.E+12	5	1.E+12	50	1.E+13
03086000	Sewickley	Mixed	07/31/01	26,300	20	1.E+13	<5	3.E+12	120	8.E+13
03086000	Sewickley	Mixed	08/14/01	19,600	460	2.E+14	10	5.E+12	560	3.E+14
03086000	Sewickley	Mixed	08/21/01	6,480	10	2.E+12	5	8.E+11	25	4.E+12
03049652	Oakmont	Wet	08/08/01	3,350	<5	4.E+11	<5	4.E+11	<5	4.E+11
03049652	Oakmont	Wet	08/09/01	3,830	<5	5.E+11	<5	5.E+11	5	5.E+11
03049652	Oakmont	Wet	08/10/01	3,860	20	2.E+12	<5	5.E+11	35	3.E+12
03049652	Oakmont	Wet	08/28/01	4,640	25	3.E+12	<5	6.E+11	50	6.E+12
03049652	Oakmont	Wet	08/29/01	4,040	<5	5.E+11	<5	5.E+11	5	5.E+11
03049652	Oakmont	Wet	08/30/01	4,520	15	2.E+12	25	3.E+12	10	1.E+12
03049652	Oakmont	Wet	09/25/01	3,480	15	1.E+12	<5	4.E+11	5	4.E+11
03049652	Oakmont	Wet	09/27/01	4,350	15	2.E+12	<5	5.E+11	15	2.E+12
03049832	9th St. Bridge	Wet	08/08/01	4,440	2,700	3.E+14	230	2.E+13	4,400	5.E+14
03049832	9th St. Bridge	Wet	08/09/01	3,710	440	4.E+13	20	2.E+12	560	5.E+13
03049832	9th St. Bridge	Wet	08/10/01	4,510	6,400	7.E+14	225	2.E+13	14,000	2.E+15
03049832	9th St. Bridge	Wet	08/28/01	5,220	420	5.E+13	20	3.E+12	750	1.E+14
03049832	9th St. Bridge	Wet	08/29/01	4,890	2,200	3.E+14	265	3.E+13	3,300	4.E+14
03049832	9th St. Bridge	Wet	08/30/01	4,720	35	4.E+12	100	1.E+13	540	6.E+13
03049832	9th St. Bridge	Wet	09/25/01	3,630	690	6.E+13	5	4.E+11	880	8.E+13
03049832	9th St. Bridge	Wet	09/26/01	5,450	220	3.E+13	10	1.E+12	580	8.E+13
03049832	9th St. Bridge	Wet	09/27/01	3,770	35	3.E+12	5	5.E+11	90	8.E+12
03085000	Braddock	Wet	08/08/01	5,460	6,000	8.E+14	125	2.E+13	8,000	1.E+15
03085000	Braddock	Wet	08/09/01	4,210	35	4.E+12	20	2.E+12	90	9.E+12
03085000	Braddock	Wet	08/10/01	3,140	510	4.E+13	15	1.E+12	840	6.E+13
03085000	Braddock	Wet	08/28/01	5,670	520	7.E+13	130	2.E+13	1,500	2.E+14
03085000	Braddock	Wet	08/29/01	5,650	2,000	3.E+14	250	3.E+13	1,700	2.E+14
03085000	Braddock	Wet	08/30/01	4,900	50	6.E+12	150	2.E+13	740	9.E+13
03085000	Braddock	Wet	09/25/01	7,770	1,600	3.E+14	220	4.E+13	15,000	3.E+15
03085000	Braddock	Wet	09/26/01	9,090	90	2.E+13	15	3.E+12	250	6.E+13
03085000	Braddock	Wet	09/27/01	5,400	570	8.E+13	35	5.E+12	320	4.E+13

Table 8. Estimated daily loads of fecal-indicator bacteria within the Allegheny, Monongahela, and Ohio Rivers near Pittsburgh, Pennsylvania, July-September 2001—Continued.

U.S. Geological Survey station number	Site name	Event	Date	Streamflow, in cubic feet per second	*Escherichia coli*, in colonies per 100 milliliter	*Escherichia coli* load, in colonies per day	*Enterococci*, in colonies per 100 milliliters	*Enterococci* load, in colonies per day	Fecal coliform, in colonies per 100 milliliters	Fecal coliform load, in colonies per day
03085150	Smithfield St. Bridge	Wet	08/08/01	5,270	1,800	2.E+14	130	2.E+13	3,500	5.E+14
03085150	Smithfield St. Bridge	Wet	08/09/01	3,800	180	2.E+13	15	1.E+12	3,400	3.E+14
03085150	Smithfield St. Bridge	Wet	08/10/01	3,010	2,000	1.E+14	195	1.E+13	2,800	2.E+14
03085150	Smithfield St. Bridge	Wet	08/28/01	5,620	280	4.E+13	20	3.E+12	650	9.E+13
03085150	Smithfield St. Bridge	Wet	08/29/01	5,400	2,300	3.E+14	90	1.E+13	2,600	3.E+14
03085150	Smithfield St. Bridge	Wet	08/30/01	5,740	260	4.E+13	685	1.E+14	3,900	5.E+14
03085150	Smithfield St. Bridge	Wet	09/25/01	7,550	960	2.E+14	<5	9.E+11	810	1.E+14
03085150	Smithfield St. Bridge	Wet	09/26/01	9,070	870	2.E+14	5	1.E+12	880	2.E+14
03085150	Smithfield St. Bridge	Wet	09/27/01	2,880	500	4.E+13	10	7.E+11	230	2.E+13
03086000	Sewickley	Wet	08/08/01	11,600	1,300	4.E+14	350	1.E+14	650	2.E+14
03086000	Sewickley	Wet	08/09/01	8,110	400	8.E+13	115	2.E+13	580	1.E+14
03086000	Sewickley	Wet	08/10/01	8,990	420	9.E+13	70	2.E+13	250	5.E+13
03086000	Sewickley	Wet	08/28/01	14,300	240	8.E+13	10	3.E+12	760	3.E+14
03086000	Sewickley	Wet	08/29/01	13,000	2,300	7.E+14	310	1.E+14	2,200	7.E+14
03086000	Sewickley	Wet	08/30/01	9,400	2,300	5.E+14	180	4.E+13	770	2.E+14
03086000	Sewickley	Wet	09/26/01	11,500	2,000	6.E+14	20	6.E+12	3,200	9.E+14
03086000	Sewickley	Wet	09/28/01	8,380	140	3.E+13	15	3.E+12	230	5.E+13

Summary and Conclusions

The Allegheny County Health Department (ACHD) and U.S. Geological Survey (USGS) implemented a water-quality-monitoring program in July through September 2001 to assess the occurrence and distribution of fecal-indicator bacteria in the Allegheny, Monongahela, and Ohio Rivers (Three Rivers) near Pittsburgh, Pa. Water-quality samples were collected and streamflow measurements were made during dry-, mixed-, and wet-weather conditions at five sampling sites on the Three Rivers. Water samples were collected weekly to establish baseline conditions and during successive days after three wet-weather events.

Samples were collected by the USGS and analyzed by the ACHD Laboratory for concentrations of fecal coliform (FC), *Escherichia coli (E. coli)*, and *enterococci* bacteria. Fecal-indicator bacteria reported in bank and composite samples were used to evaluate the distribution and mixing of bacteria source streams within receiving waters such as the Three Rivers. At each site, left-bank and right-bank samples were collected in addition to a composite sample (a discharge-weighted sample representative of the channel cross section as a whole).

Wet-weather concentrations exceeded those reported during dry-weather events for all sites, except the Allegheny River at Oakmont. At this site, dilution during wet-weather events or the lack of source streams upgradient of the site may cause this anomaly. Additionally, based on single-event, water-quality data, fecal-indicator bacteria concentrations of *E. coli* and FC during wet-weather events exceeded State and Federal water-quality standards (WQS). Concentrations of *enterococci*, *E. coli*, and FC during dry-weather events were greater than the WQS in 11, 28, and 28 percent of the samples, respectively; during mixed-weather events, concentrations of fecal-indicator bacteria were greater than the WQS in 28, 37, and 43 percent of the samples, respectively; and during wet-weather samples, concentrations of fecal-indicator bacteria were greater than the WQS in 56, 71, and 81 percent of samples, respectively.

It is difficult to establish a short-term trend in concentrations of fecal-indicator bacteria as a function of time after a wet-weather event because of factors including the spatial variability of sources contributing fecal material, dry-weather discharges, resuspension of bottom sediments, and flow augmentation from upstream reservoirs. Relative to *E. coli* and *enterococci*, FC concentrations appear to decrease with time, which may be attributed to the greater die-off rate for FC bacteria.

Fecal-indicator bacteria concentrations at a station are dependent on the spatial distribution of point sources upstream of the station, the time of travel, rate of decay, and the degree of mixing and resuspension.

In general, the bacteria concentrations in the bank samples collected at each site were greater than in the composite sample. This is attributed in part to incomplete mixing of source discharges such as combined sewer overflows/sanitary sewer overflows and tributaries adjacent to the river banks. Depending on the difference in the momentum between the point source and the receiving water, the point discharges may be strongly deflected and have a tendency to hug the side of the receiving water channel. This is particularly true within the near-field mixing region, where the jet characteristics of the discharge (momentum, buoyancy, and outfall geometry) dominate. As the plume travels downstream, these characteristics become less important, and the characteristics of the receiving water (momentum, velocity distribution, channel geometry, buoyant spreading, and diffusion) dominate the mixing process. The point at which mixing becomes more uniform is based on the distribution of additional point discharges downstream and receiving water hydrodynamics. If conditions are well-mixed, peak concentrations would be expected to coincide with that part of a channel where the maximum velocity occurs.

To evaluate the significance of the fecal-indicator bacteria counts and turbidity reported in grab and composite samples during dry-, mixed-, and wet-weather events, data sets were evaluated using Wilcoxon rank sum tests. Tests were conducted using each of the fecal-indicator bacteria by station and lumped based on weather event. For example, fecal coliform counts reported in the left-bank sample were compared against the right-bank and composite samples, respectively, for the Sewickley site during dry-, mixed-, and wet-weather events.

The information presented in this report may be helpful to water-resources managers in development of TMDLs for the Three Rivers region.

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Appendix 1. Summary of Streamflow and Water-Quality Samples

[lat, latitude; long, longitude; mi, mile; mi^2, square mile; inst., instantaneous; ft fm r bk, feet from right bank; mg/L, milligram per liter; ∝S/cm, microsiemens per centimeter; deg C, degrees Celsius; ft fm l bank; feet from left bank; NTU, nephelometric turbidity units; col/100 mL, colonies per 100 milliliters; 9, surface-water sample; R, quality-control sample from surface water; --, no data; <, less than]

03049652 ALLEGHENY RIVER AT OAKMONT, PA

LOCATION.--Lat 40°31'39", long 79°50'51", Allegheny County, Hydrologic Unit 05010009, at Hulton bridge at Oakmont, 0.7 mi downstream from Deer Creek, at river mile 12.7.

DRAINAGE AREA.--11,577 mi^2.

WATER-QUALITY DATA, WATER YEAR OCTOBER 2000 TO SEPTEMBER 2001

DATE	TIME	MEDIUM CODE	DIS-CHARGE, INST. CUBIC FEET PER SECOND (00061)	SAMPLE LOC-ATION, CROSS SECTION (FT FM R BK) (72103)	OXYGEN, DIS-SOLVED (MG/L) (00300)	PH WATER WHOLE FIELD (STAND-ARD UNITS) (00400)	SPE-CIFIC CON-DUCT-ANCE (∝S/CM) (00095)	TEMPER-ATURE WATER (DEG C) (00010)	SAMPLE LOC-ATION, CROSS SECTION (FT FM L BANK) (00009)
JUL									
12...	1505	9	4360	--	6.8	7.3	354	27.0	25.0
12...	1620	9	4360	--	--	7.5	359	27.5	--
12...	1630	9	4360	25.0	7.2	7.4	373	27.0	--
18...	1440	9	4150	40.0	9.8	7.8	411	29.0	--
18...	1500	9	4150	--	--	8.0	397	29.0	--
18...	1510	9	4150	--	9.8	7.8	383	29.0	30.0
24...	1440	9	4040	30.0	9.6	7.8	374	29.0	--
24...	1500	9	4040	--	--	7.9	384	29.0	--
24...	1515	9	4040	--	9.6	7.8	375	29.0	30.0
31...	1510	9	4040	40.0	9.1	8.1	363	33.0	--
31...	1530	9	4040	--	--	7.4	369	33.0	--
31...	1535	R	4040	--	--	7.4	369	33.0	--
31...	1543	9	4040	--	9.1	7.6	345	33.0	35.0
AUG									
07...	1430	9	5650	40.0	9.7	8.0	349	32.0	--
07...	1445	9	5650	--	--	7.9	352	32.0	--
07...	1500	9	5650	--	9.7	7.9	339	32.0	45.0
08...	1445	9	3350	20.0	10.9	8.0	368	33.0	--
08...	1500	9	3350	--	--	8.1	382	33.0	--
08...	1515	9	3350	--	10.9	8.0	365	33.0	45.0
09...	1310	9	3830	40.0	10.4	8.4	393	31.5	--
09...	1325	9	3830	--	--	8.0	360	30.1	--
09...	1330	R	3830	--	--	8.0	360	30.1	--
09...	1335	9	3830	--	--	8.0	368	32.0	45.0
10...	1440	9	3860	40.0	8.9	8.0	371	31.5	--
10...	1505	9	3860	--	--	7.9	376	31.5	--
10...	1515	9	3860	--	8.9	8.0	350	31.5	45.0
14...	1300	9	3410	40.0	9.4	7.8	394	21.0	--
14...	1330	9	3410	--	--	7.6	392	28.0	--
14...	1340	9	3410	--	9.4	7.8	371	29.0	45.0
21...	1545	9	2810	40.0	10.2	7.9	397	29.5	--
21...	1600	9	2810	--	--	7.8	401	29.5	--
21...	1610	9	2810	--	10.2	7.9	387	29.5	20.0
28...	1540	9	4640	40.0	11.1	7.0	405	23.0	--
28...	1550	9	4640	--	--	7.2	392	24.1	--
28...	1600	9	4640	--	11.1	7.1	373	24.3	40.0
29...	1445	9	4040	40.0	12.5	7.1	393	24.5	--
29...	1500	9	4040	--	--	7.4	392	27.0	--
29...	1515	9	4040	--	12.5	7.3	362	27.0	50.0
30...	1246	9	4520	40.0	11.3	8.0	399	27.0	--
30...	1300	9	4520	--	--	7.4	393	27.0	--
30...	1310	9	4520	--	11.3	7.6	386	27.0	50.0
SEP									
04...	1410	9	3980	40.0	12.2	7.9	382	26.0	--
04...	1430	9	3980	--	--	8.0	388	26.5	--
04...	1440	9	3980	--	12.2	7.9	360	26.5	50.0
18...	1300	9	3630	--	8.6	7.8	288	24.0	40.0
18...	1400	9	3630	--	--	7.8	303	28.0	--
18...	1415	9	3630	45.0	9.4	7.9	293	24.0	--
25...	1400	9	3480	--	8.9	7.7	384	22.0	213
25...	1500	9	3480	--	--	7.6	399	20.5	--
25...	1515	9	3480	69.0	9.2	7.8	397	21.5	--
27...	1405	9	4350	--	10.0	7.8	358	21.0	150
27...	1520	9	4350	--	--	7.8	362	20.0	--
27...	1530	9	4350	70.0	9.7	7.9	376	21.0	--

03049652 ALLEGHENY RIVER AT OAKMONT, PA—Continued

WATER-QUALITY DATA, WATER YEAR OCTOBER 2000 TO SEPTEMBER 2001

DATE	MEDIUM CODE	SAMPLE LOC- ATION, CROSS SECTION (FT FM R BK) (72103)	TUR- BID- ITY (NTU) (00076)	E COLI, MTEC MF WATER (COL/ 100 ML) (31633)	ENTERO- COCCI, ME MF, WATER (COL/ 100 ML) (31649)	FECAL COLI- FORM, MFC MF, WATER (COL/ 100 ML) (31616)	SAMPLE LOC- ATION, CROSS SECTION (FT FM L BANK) (00009)
JUL							
12...	9	--	7.4	10	5	90	25.0
12...	9	--	10	220	5	210	--
12...	9	25.0	6.2	20	<5	100	--
18...	9	40.0	4.8	20	30	45	--
18...	9	--	3.8	40	<5	25	--
18...	9	--	6.1	95	35	85	30.0
24...	9	30.0	--	10	5	30	--
24...	9	--	--	15	<5	30	--
24...	9	--	--	180	75	230	30.0
31...	9	40.0	4.8	15	<5	55	--
31...	9	--	6.9	<5	<5	<5	--
31...	R	--	6.9	<5	<5	<5	--
31...	9	--	6.8	35	40	30	35.0
AUG							
07...	9	40.0	3.7	35	5	75	--
07...	9	--	7.3	15	<5	40	--
07...	9	--	3.7	40	5	35	45.0
08...	9	20.0	8.3	25	<5	15	--
08...	9	--	6.2	<5	<5	<5	--
08...	9	--	8.3	20	30	35	45.0
09...	9	40.0	4.6	10	15	30	--
09...	9	--	4.6	<5	<5	5	--
09...	R	--	4.6	<5	<5	<5	--
09...	9	--	5.9	15	<5	65	45.0
10...	9	40.0	4.6	60	45	100	--
10...	9	--	6.3	20	<5	35	--
10...	9	--	5.4	55	20	120	45.0
14...	9	40.0	3.6	5	<5	70	--
14...	9	--	4.5	45	<5	65	--
14...	9	--	3.5	M	20	280	45.0
21...	9	40.0	6.2	25	50	50	--
21...	9	--	5.8	20	10	30	--
21...	9	--	6.8	130	20	210	20.0
28...	9	40.0	8.6	820	690	960	--
28...	9	--	7.4	25	<5	50	--
28...	9	--	9.9	370	240	660	40.0
29...	9	40.0	10	60	80	45	--
29...	9	--	9.0	<5	<5	5	--
29...	9	--	6.1	400	40	410	50.0
30...	9	40.0	6.5	140	75	180	--
30...	9	--	7.8	15	25	10	--
30...	9	--	6.9	55	20	220	50.0
SEP							
04...	9	40.0	7.8	110	20	330	--
04...	9	--	9.4	85	<5	75	--
04...	9	--	9.9	140	5	130	50.0
18...	9	--	5.7	40	10	20	40.0
18...	9	--	5.6	20	<5	20	--
18...	9	45.0	6.1	30	<5	60	--
25...	9	--	7.0	55	5	270	213
25...	9	--	7.8	15	<5	5	--
25...	9	69.0	8.7	130	20	320	--
27...	9	--	5.7	35	<5	33	150
27...	9	--	7.3	15	<5	15	--
27...	9	70.0	5.7	45	5	95	--

03049832 ALLEGHENY RIVER AT 9TH STREET BRIDGE AT PITTSBURGH, PA

LOCATION.--Lat 40°26'47", long 79°59'58", Allegheny County, Hydrologic Unit 05010009, at 9th Street bridge in Pittsburgh, at river mile 0.7.

DRAINAGE AREA.--11,710 mi^2.

WATER-QUALITY DATA, WATER YEAR OCTOBER 2000 TO SEPTEMBER 2001

DATE	TIME	MEDIUM CODE	DIS-CHARGE, INST. CUBIC FEET PER SECOND (00061)	SAMPLE LOC-ATION, CROSS SECTION (FT FM R BK) (72103)	OXYGEN, DIS-SOLVED (MG/L) (00300)	PH WATER WHOLE FIELD (STAND-ARD UNITS) (00400)	SPE-CIFIC CON-DUCT-ANCE (∝S/CM) (00095)	TEMPER-ATURE WATER (DEG C) (00010)	SAMPLE LOC-ATION, CROSS SECTION (FT FM L BANK) (00009)
JUL									
12...	1050	9	4130	--	6.6	7.5	358	26.0	20.0
12...	1110	9	4130	--	7.7	7.4	358	26.0	--
12...	1135	9	4130	20.0	7.2	7.4	366	26.0	--
18...	1000	9	4080	--	7.3	7.4	399	26.5	20.0
18...	1100	9	4080	--	7.3	7.5	401	26.5	--
18...	1110	9	4080	20.0	6.6	7.5	405	26.5	--
24...	1005	9	5910	--	6.7	7.4	375	28.0	20.0
24...	1120	9	5910	--	7.6	7.6	376	28.5	--
24...	1125	9	5910	20.0	6.6	7.4	380	28.5	--
31...	1140	9	3530	--	7.6	7.6	396	27.5	20.0
31...	1300	9	3530	--	--	7.3	396	29.0	--
31...	1320	9	3530	20.0	7.9	8.1	396	27.0	--
AUG									
07...	1000	9	4960	--	7.1	7.2	364	28.5	25.0
07...	1127	9	4960	--	--	7.4	364	29.0	--
07...	1135	9	4960	20.0	7.0	7.8	366	29.0	--
08...	1130	9	4440	--	6.8	7.7	343	29.5	20.0
08...	1220	9	4440	20.0	6.4	7.5	358	29.5	--
08...	1300	9	4440	--	--	7.4	346	29.5	--
09...	1000	9	3710	--	6.3	7.2	353	29.0	30.0
09...	1100	9	3710	--	--	7.5	350	30.0	--
09...	1110	9	3710	20.0	6.3	7.8	350	29.5	--
10...	1010	9	4510	--	7.4	7.8	354	29.0	20.0
10...	1030	9	4510	--	--	8.1	355	29.0	--
10...	1050	9	4510	20.0	7.4	8.1	358	29.0	--
14...	1050	9	4230	--	7.5	7.4	374	29.0	25.0
14...	1120	9	4230	--	--	7.6	375	29.0	--
14...	1135	9	4230	25.0	8.4	7.5	380	29.0	--
21...	1205	9	3140	--	8.1	7.9	369	27.0	25.0
21...	1305	9	3140	--	--	8.0	370	27.0	--
21...	1310	R	3140	--	--	8.0	370	27.0	--
21...	1315	9	3140	25.0	8.2	8.0	369	27.0	--
28...	1052	9	5220	--	9.5	6.5	388	27.0	20.0
28...	1130	9	5220	--	--	7.2	387	27.5	--
28...	1205	9	5220	20.0	9.3	6.4	389	27.5	--
29...	1245	9	4890	--	7.9	--	394	26.5	25.0
29...	1350	9	4890	--	--	--	391	27.0	--
29...	1400	9	4890	25.0	8.5	--	391	27.5	--
30...	1215	9	4720	--	9.1	7.9	415	27.0	30.0
30...	1320	9	4720	--	--	7.9	416	27.0	--
30...	1325	9	4720	25.0	9.0	7.8	426	27.5	--
SEP									
04...	1100	9	4220	--	8.7	7.1	346	25.5	30.0
04...	1145	9	4220	--	--	7.8	345	26.0	--
04...	1150	9	4220	30.0	9.2	7.2	348	26.0	--
18...	1135	9	3320	--	9.5	7.9	304	23.0	30.0
18...	1200	9	3320	--	--	7.9	305	23.0	--
18...	1210	9	3320	30.0	8.9	7.8	306	23.0	--
25...	1015	9	3630	--	8.1	7.5	436	22.0	55.0
25...	1050	9	3630	--	--	7.6	442	20.5	--
25...	1100	9	3630	40.0	7.9	7.5	443	22.0	--
26...	1355	9	5450	--	9.1	7.8	451	20.0	60.0
26...	1410	9	5450	40.0	9.2	7.7	450	20.0	--
26...	1425	9	5450	--	--	7.8	450	21.5	--
26...	1425	R	5450	--	--	7.8	450	20.5	--
27...	1230	9	3770	--	10.4	7.7	420	19.5	40.0
27...	1250	9	3770	40.0	9.9	7.7	421	20.0	--
27...	1310	9	3770	--	--	7.6	418	19.5	--
27...	1310	R	3770	--	--	7.6	418	19.5	--

03049832 ALLEGHENY RIVER AT 9TH STREET BRIDGE AT PITTSBURGH, PA—Continued

WATER-QUALITY DATA, WATER YEAR OCTOBER 2000 TO SEPTEMBER 2001

DATE	MEDIUM CODE	SAMPLE LOC-ATION, CROSS SECTION (FT FM R BK) (72103)	TUR-BID-ITY (NTU) (00076)	E COLI, MTEC MF WATER (COL/ 100 ML) (31633)	ENTERO-COCCI, ME MF, WATER (COL/ 100 ML) (31649)	FECAL COLI-FORM, MFC MF, WATER (COL/ 100 ML) (31616)	SAMPLE LOC-ATION, CROSS SECTION (FT FM L BANK) (00009)
JUL							
12...	9	--	7.5	70	20	180	20.0
12...	9	--	9.8	130	<5	180	--
12...	9	20.0	5.8	65	10	160	--
18...	9	--	7.7	9	<5	110	20.0
18...	9	--	13	3	5	55	--
18...	9	20.0	6.7	45	15	40	--
24...	9	--	5.1	230	35	460	20.0
24...	9	--	6.9	140	20	290	--
24...	9	20.0	4.5	45	40	130	--
31...	9	--	4.5	10	<5	40	20.0
31...	9	--	7.8	5	<5	25	--
31...	9	20.0	5.1	35	25	60	--
AUG							
07...	9	--	4.2	<5	10	70	25.0
07...	9	--	6.5	20	5	30	--
07...	9	20.0	3.1	45	5	55	--
08...	9	--	3.4	2900	200	7600	20.0
08...	9	20.0	2.9	600	150	1600	--
08...	9	--	5.6	2700	230	4400	--
09...	9	--	6.1	1800	85	1600	30.0
09...	9	--	7.9	440	20	560	--
09...	9	20.0	4.9	900	50	150	--
10...	9	--	3.6	240	575	230	20.0
10...	9	--	120	6400	225	14000	--
10...	9	20.0	3.3	4200	220	21000	--
14...	9	--	3.4	85	5	200	25.0
14...	9	--	5.6	75	<5	85	--
14...	9	25.0	3.7	160	15	6900	--
21...	9	--	4.4	160	5	260	25.0
21...	9	--	7.1	<5	<5	<5	--
21...	R	--	--	<5	<5	5	--
21...	9	25.0	3.7	60	10	280	--
28...	9	--	6.0	460	25	1500	20.0
28...	9	--	6.0	420	20	750	--
28...	9	20.0	5.6	160	60	650	--
29...	9	--	9.8	280	200	5100	25.0
29...	9	--	17	2200	265	3300	--
29...	9	25.0	9.9	2000	360	3700	--
30...	9	--	4.7	440	65	620	30.0
30...	9	--	9.9	35	100	540	--
30...	9	25.0	6.2	30	110	640	--
SEP							
04...	9	--	6.2	140	10	420	30.0
04...	9	--	11	<5	<5	15	--
04...	9	30.0	7.6	190	<5	360	--
18...	9	--	5.3	40	5	35	30.0
18...	9	--	8.2	5	<5	5	--
18...	9	30.0	4.5	25	15	50	--
25...	9	--	8.1	5200	525	11000	55.0
25...	9	--	12	690	5	880	--
25...	9	40.0	8.8	7900	380	10000	--
26...	9	--	7.0	400	20	690	60.0
26...	9	40.0	6.9	730	20	830	--
26...	9	--	7.6	220	10	580	--
26...	R	--	7.6	150	<5	540	--
27...	9	--	5.6	65	5	140	40.0
27...	9	40.0	5.5	120	5	160	--
27...	9	--	7.0	35	5	90	--
27...	R	--	7.0	45	<5	120	--

03085000 MONONGAHELA RIVER AT BRADDOCK, PA

LOCATION.--Lat 40°23'28", long 79°51'30", Allegheny County, Hydrologic Unit 05020005, 300 ft upstream from dam at lock 2 at Braddock, 1,700 ft downstream from Turtle Creek, and 11.2 mi upstream of confluence with Allegheny River.

DRAINAGE AREA.--7,337 mi^2.

WATER-QUALITY DATA, WATER YEAR OCTOBER 2000 TO SEPTEMBER 2001

DATE	TIME	MEDIUM CODE	DIS-CHARGE, INST. CUBIC FEET PER SECOND (00061)	SAMPLE LOC-ATION, CROSS SECTION (FT FM R BK) (72103)	OXYGEN, DIS-SOLVED (MG/L) (00300)	PH WATER WHOLE FIELD (STAND-ARD UNITS) (00400)	SPE-CIFIC CON-DUCT-ANCE (∝S/CM) (00095)	TEMPER-ATURE WATER (DEG C) (00010)	SAMPLE LOC-ATION, CROSS SECTION (FT FM L BANK) (00009)
JUL									
12...	1510	9	14800	--	7.8	7.5	298	27.0	40.0
12...	1530	9	14800	--	--	7.8	323	25.5	--
12...	1540	9	14800	40.0	7.8	7.6	287	25.5	--
18...	1435	9	3670	30.0	6.7	7.7	389	27.0	--
18...	1530	9	3670	--	--	7.6	387	27.5	--
18...	1540	9	3670	--	6.7	7.8	385	26.5	40.0
24...	1405	9	3180	--	6.5	7.5	314	28.5	40.0
24...	1500	9	3180	--	--	7.4	321	29.0	--
24...	1510	9	3180	30.0	7.3	7.6	321	28.0	--
31...	0840	9	21800	--	7.7	7.0	275	24.5	20.0
31...	1005	9	21800	20.0	7.7	7.2	275	25.0	--
31...	1040	9	21800	--	--	7.3	262	26.0	--
AUG									
07...	0810	9	4720	--	6.7	7.4	300	26.0	20.0
07...	0850	9	4720	20.0	6.6	7.4	297	26.0	--
07...	0910	9	4720	--	--	7.6	298	26.5	--
08...	1000	9	5460	--	7.0	7.5	308	27.0	50.0
08...	1030	9	5460	--	--	7.5	307	27.5	--
08...	1040	9	5460	20.0	6.5	7.6	313	27.0	--
09...	0830	9	4210	--	6.2	7.2	317	28.5	25.0
09...	0855	9	4210	--	--	7.4	320	28.5	--
09...	0902	9	4210	25.0	6.2	7.4	322	28.5	--
10...	0815	9	3140	--	7.3	7.8	319	28.5	25.0
10...	0840	9	3140	--	--	7.9	327	28.0	--
10...	0900	9	3140	40.0	6.6	7.6	324	28.5	--
14...	0830	9	11600	--	8.5	7.7	300	27.0	25.0
14...	0945	9	11600	--	--	7.7	296	27.0	--
14...	1000	9	11600	25.0	8.2	7.7	308	27.5	--
21...	0925	9	3340	--	8.0	7.6	306	25.0	25.0
21...	1025	9	3340	--	--	7.7	305	25.0	--
21...	1035	9	3340	25.0	7.8	7.5	308	25.0	--
28...	0845	9	5670	--	8.7	7.9	339	27.0	20.0
28...	0950	9	5670	--	--	8.0	337	27.5	--
28...	1010	9	5670	50.0	8.0	7.0	337	29.0	--
29...	1020	9	5650	--	7.9	7.4	330	27.5	25.0
29...	1120	9	5650	--	--	7.5	329	27.5	--
29...	1130	9	5650	25.0	7.6	7.4	332	28.0	--
30...	0940	9	4900	--	7.8	7.2	347	26.5	25.0
30...	1035	9	4900	--	--	7.4	353	26.5	--
30...	1045	9	4900	60.0	7.4	7.2	351	26.5	--
SEP									
04...	0900	9	5120	--	8.4	7.9	408	26.5	30.0
04...	1000	9	5120	--	--	7.6	404	26.5	--
04...	1015	9	5120	30.0	7.5	7.4	410	26.5	--
18...	0810	9	2350	--	8.2	7.6	328	23.0	30.0
18...	0915	9	2350	--	--	7.6	337	22.5	--
18...	0930	9	2350	30.0	8.0	7.6	331	23.0	--
25...	0845	9	7770	--	8.5	7.4	419	22.5	25.0
25...	0915	9	7770	30.0	8.2	7.6	426	21.5	--
25...	0930	9	7770	--	--	7.5	418	21.0	--
25...	0935	R	7770	--	--	7.5	418	21.0	--
26...	1230	9	9090	--	8.7	7.5	438	22.5	25.0
26...	1250	9	9090	30.0	8.3	7.5	443	22.5	--
26...	1315	9	9090	--	--	7.6	436	22.0	--
27...	0930	9	5400	--	9.9	7.5	446	20.0	25.0
27...	1000	9	5400	40.0	9.8	7.6	445	20.0	--
27...	1010	9	5400	--	--	7.6	446	19.5	--

03085000 MONONGAHELA RIVER AT BRADDOCK, PA—Continued

WATER-QUALITY DATA, WATER YEAR OCTOBER 2000 TO SEPTEMBER 2001

DATE	MEDIUM CODE	SAMPLE LOC- ATION, CROSS SECTION (FT FM R BK) (72103)	TUR- BID- ITY (NTU) (00076)	E COLI, MTEC MF WATER (COL/ 100 ML) (31633)	ENTERO- COCCI, ME MF, WATER (COL/ 100 ML) (31649)	FECAL COLI- FORM, MFC MF, WATER (COL/ 100 ML) (31616)	SAMPLE LOC- ATION, CROSS SECTION (FT FM L BANK) (00009)
JUL							
12...	9	--	--	380	85	70	40.0
12...	9	--	--	<100	<5	<5	--
12...	9	40.0	--	20	30	850	--
18...	9	30.0	15	120	<5	160	--
18...	9	--	14	120	<5	160	--
18...	9	--	12	80	<5	65	40.0
24...	9	--	11	80	10	260	40.0
24...	9	--	15	120	5	170	--
24...	9	30.0	10	40	<5	100	--
31...	9	--	75	45	35	300	20.0
31...	9	20.0	30	45	15	170	--
31...	9	--	45	120	30	260	--
AUG							
07...	9	--	12	960	20	340	20.0
07...	9	20.0	10	140	15	290	--
07...	9	--	13	320	15	520	--
08...	9	--	14	400	50	760	50.0
08...	9	--	14	6000	125	8000	--
08...	9	20.0	10	12000	630	14000	--
09...	9	--	15	280	130	850	25.0
09...	9	--	16	35	20	90	--
09...	9	25.0	12	420	30	850	--
10...	9	--	4.9	1100	55	1400	25.0
10...	9	--	7.9	510	15	840	--
10...	9	40.0	5.4	11000	530	23000	--
14...	9	--	14	320	<5	760	25.0
14...	9	--	16	230	15	680	--
14...	9	25.0	10	140	20	220	--
21...	9	--	9.7	290	35	440	25.0
21...	9	--	14	320	45	640	--
21...	9	25.0	9.7	360	60	580	--
28...	9	--	14	100	45	450	20.0
28...	9	--	15	520	130	1500	--
28...	9	50.0	13	200	90	1100	--
29...	9	--	14	2000	190	1600	25.0
29...	9	--	15	2000	250	1700	--
29...	9	25.0	14	1100	335	2300	--
30...	9	--	19	60	185	6400	25.0
30...	9	--	20	50	150	740	--
30...	9	60.0	18	50	155	710	--
SEP							
04...	9	--	12	<5	<5	100	30.0
04...	9	--	13	100	5	160	--
04...	9	30.0	7.6	40	<5	150	--
18...	9	--	13	170	15	130	30.0
18...	9	--	14	30	5	40	--
18...	9	30.0	11	120	5	140	--
25...	9	--	12	440	30	640	25.0
25...	9	30.0	13	2600	175	19000	--
25...	9	--	18	1600	220	15000	--
25...	R	--	18	1400	370	19000	--
26...	9	--	16	1000	10	1800	25.0
26...	9	30.0	14	760	35	730	--
26...	9	--	17	90	15	250	--
27...	9	--	11	860	15	310	25.0
27...	9	40.0	11	480	30	320	--
27...	9	--	12	570	35	320	--

03085150 MONONGAHELA RIVER AT PITTSBURGH, PA

LOCATION.--Lat 40°26'06", long 80°00'08", Allegheny County, Hydrologic Unit 05020005, at Smithfield Street bridge in Pittsburgh, at river mile 0.8.

DRAINAGE AREA.--7,367 mi^2.

WATER-QUALITY DATA, WATER YEAR OCTOBER 2000 TO SEPTEMBER 2001

DATE	TIME	MEDIUM CODE	DIS-CHARGE, INST. CUBIC FEET PER SECOND (00061)	SAMPLE LOC-ATION, CROSS SECTION (FT FM R BK) (72103)	OXYGEN, DIS-SOLVED (MG/L) (00300)	PH WATER WHOLE FIELD (STAND-ARD UNITS) (00400)	SPE-CIFIC CON-DUCT-ANCE (∝S/CM) (00095)	TEMPER-ATURE WATER (DEG C) (00010)	SAMPLE LOC-ATION, CROSS SECTION (FT FM L BANK) (00009)
JUL									
12...	1325	9	14000	--	--	7.5	260	24.0	--
12...	1330	9	14000	35.0	6.7	7.6	269	24.5	--
18...	1210	9	3080	--	7.2	7.7	317	25.0	60.0
18...	1310	9	3080	--	--	7.6	315	26.0	--
18...	1315	9	3080	20.0	7.4	7.5	315	25.0	--
24...	1240	9	3180	--	7.1	7.9	316	28.0	30.0
24...	1325	9	3180	--	--	7.8	312	30.0	--
24...	1330	9	3180	20.0	7.1	7.6	315	28.0	--
31...	1400	9	19900	--	7.1	7.3	278	25.0	30.0
31...	1450	9	19900	--	--	7.2	279	26.0	--
31...	1510	9	19900	20.0	7.2	7.2	290	25.0	--
AUG									
07...	1230	9	5060	--	7.1	7.7	303	26.0	20.0
07...	1325	9	5060	--	--	7.7	300	27.0	--
07...	1345	9	5060	20.0	7.5	7.7	301	27.0	--
08...	1410	9	5270	--	7.6	7.7	293	28.0	20.0
08...	1440	9	5270	--	--	7.6	292	27.0	--
08...	1445	9	5270	20.0	6.5	7.9	288	27.0	--
09...	1225	9	3800	--	7.0	7.6	300	28.0	20.0
09...	1315	9	3800	25.0	7.0	7.6	300	28.0	--
09...	1350	9	3800	--	--	7.2	298	29.0	--
10...	1140	9	3010	--	8.0	7.6	307	28.0	30.0
10...	1200	9	3010	--	--	7.6	307	28.0	--
10...	1220	9	3010	30.0	7.9	7.7	307	28.0	--
14...	1300	9	10700	--	7.6	7.2	313	29.0	30.0
14...	1400	9	10700	--	--	7.2	309	29.0	--
14...	1415	9	10700	30.0	7.4	7.3	311	29.0	--
21...	1400	9	3030	--	8.2	7.6	298	26.0	57.0
21...	1445	9	3030	--	8.3	7.6	298	26.0	--
21...	1500	9	3030	25.0	8.3	7.6	298	26.0	--
28...	1300	9	5620	--	8.5	4.6	336	27.0	20.0
28...	1355	9	5620	--	--	4.8	336	27.0	--
28...	1400	9	5620	20.0	8.9	5.4	336	27.0	--
29...	1430	9	5400	--	7.8	7.2	337	27.0	20.0
29...	1525	9	5400	--	--	7.2	331	28.0	--
29...	1530	R	5400	--	--	7.2	331	28.0	--
29...	1535	9	5400	20.0	7.3	7.2	343	28.0	--
30...	1400	9	5740	--	7.8	7.4	331	28.0	20.0
30...	1450	9	5740	--	--	7.6	328	28.0	--
30...	1500	9	5740	20.0	7.9	7.6	326	28.0	--
SEP									
04...	1300	9	5800	--	8.1	7.1	406	26.0	30.0
04...	1350	9	5800	--	--	7.5	407	26.0	--
04...	1400	9	5800	30.0	8.3	7.8	407	26.0	--
18...	1000	9	2700	--	9.4	8.2	352	24.0	30.0
18...	1045	9	2700	--	--	8.0	357	24.0	--
18...	1055	9	2700	30.0	9.4	8.2	353	24.0	--
25...	1120	9	7550	--	7.9	7.5	484	23.0	40.0
25...	1145	9	7550	50.0	7.9	7.5	486	23.0	--
25...	1205	9	7550	--	--	7.6	485	22.0	--
26...	1445	9	9070	--	8.3	7.7	439	21.0	60.0
26...	1500	9	9070	70.0	8.3	7.8	444	21.0	--
26...	1530	9	9070	--	--	7.6	450	21.0	--
27...	1050	9	2880	--	8.7	7.3	444	21.0	60.0
27...	1055	R	2880	--	8.7	7.3	444	21.0	60.0
27...	1110	9	2880	60.0	8.9	7.4	445	21.0	--
27...	1130	9	2880	--	--	7.4	445	21.0	--

03085150 MONONGAHELA RIVER AT PITTSBURGH, PA—Continued

WATER-QUALITY DATA, WATER YEAR OCTOBER 2000 TO SEPTEMBER 2001

DATE	MEDIUM CODE	SAMPLE LOC- ATION, CROSS SECTION (FT FM R BK) (72103)	TUR- BID- ITY (NTU) (00076)	E COLI, MTEC MF WATER (COL/ 100 ML) (31633)	ENTERO- COCCI, ME MF, WATER (COL/ 100 ML) (31649)	FECAL COLI- FORM, MFC MF, WATER (COL/ 100 ML) (31616)	SAMPLE LOC- ATION, CROSS SECTION (FT FM L BANK) (00009)
JUL							
12...	9	--	45	290	60	440	--
12...	9	35.0	22	1000	150	1600	--
18...	9	--	8.7	84	10	70	60.0
18...	9	--	14	35	<5	35	--
18...	9	20.0	11	80	5	55	--
24...	9	--	6.2	590	15	500	30.0
24...	9	--	9.5	40	<5	70	--
24...	9	20.0	6.3	30	<5	60	--
31...	9	--	40	130	30	200	30.0
31...	9	--	55	K10000	15	160	--
31...	9	20.0	23	75	20	110	--
AUG							
07...	9	--	9.2	220	25	260	20.0
07...	9	--	11	30	5	120	--
07...	9	20.0	7.8	60	10	80	--
08...	9	--	8.3	1400	55	2400	20.0
08...	9	--	9.9	1800	130	3500	--
08...	9	20.0	6.1	1000	55	2100	--
09...	9	--	5.4	180	30	180	20.0
09...	9	25.0	5.4	180	30	180	--
09...	9	--	14	180	15	3400	--
10...	9	--	4.9	2400	65	2900	30.0
10...	9	--	7.9	2000	195	2800	--
10...	9	30.0	5.4	1900	350	5900	--
14...	9	--	6.8	240	65	820	30.0
14...	9	--	16	75	<5	80	--
14...	9	30.0	7.7	240	5	240	--
21...	9	--	7.6	180	35	230	57.0
21...	9	--	8.5	420	45	670	--
21...	9	25.0	8.5	420	45	670	--
28...	9	--	7.1	290	30	900	20.0
28...	9	--	39	280	20	650	--
28...	9	20.0	7.7	220	5	540	--
29...	9	--	11	750	235	3600	20.0
29...	9	--	12	2300	90	2600	--
29...	R	--	12	140	60	1900	--
29...	9	20.0	10	39000	1060	50000	--
30...	9	--	10	70	85	620	20.0
30...	9	--	14	260	685	3900	--
30...	9	20.0	7.5	100	60	680	--
SEP							
04...	9	--	8.9	3100	40	3100	30.0
04...	9	--	12	180	<5	740	--
04...	9	30.0	12	9200	150	13000	--
18...	9	--	8.1	25	10	75	30.0
18...	9	--	13	5	5	10	--
18...	9	30.0	6.9	40	10	45	--
25...	9	--	9.8	1900	65	18000	40.0
25...	9	50.0	9.4	1600	10	16000	--
25...	9	--	12	960	<5	810	--
26...	9	--	12	1300	35	2800	60.0
26...	9	70.0	8.6	340	20	620	--
26...	9	--	11	870	5	880	--
27...	9	--	9.2	260	10	280	60.0
27...	R	--	9.2	320	5	270	60.0
27...	9	60.0	7.2	240	15	180	--
27...	9	--	8.7	500	10	230	--

03086000 OHIO RIVER AT SEWICKLEY, PA

LOCATION.--Lat 40°32'57", long 80°12'21", Allegheny County, Hydrologic Unit 05030101, 50 ft upstream from Dashields Dam, 1.0 mi downstream from Narrows Run, 1.0 mi northwest of Sewickley, and 13.3 mi downstream from confluence of Allegheny and Monongahela Rivers.

DRAINAGE AREA.--19,500 mi^2, approximately.

WATER-QUALITY DATA, WATER YEAR OCTOBER 2000 TO SEPTEMBER 2001

DATE	TIME	MEDIUM CODE	DIS-CHARGE, INST. CUBIC FEET PER SECOND (00061)	SAMPLE LOC-ATION, CROSS SECTION (FT FM R BK) (72103)	OXYGEN, DIS-SOLVED (MG/L) (00300)	PH WATER WHOLE FIELD (STAND-ARD UNITS) (00400)	SPE-CIFIC CON-DUCT-ANCE (∝S/CM) (00095)	TEMPER-ATURE WATER (DEG C) (00010)	SAMPLE LOC-ATION, CROSS SECTION (FT FM L BANK) (00009)
JUL									
12...	1010	9	22600	--	--	7.7	349	26.0	20.0
12...	1100	9	22600	--	--	7.7	340	26.0	--
12...	1115	9	22600	20.0	--	7.6	350	27.0	--
18...	1005	9	8200	--	9.4	7.9	382	26.0	50.0
18...	1015	9	8200	--	--	7.7	387	26.0	--
18...	1030	9	8200	35.0	--	7.8	384	26.0	--
24...	0940	9	8300	--	9.0	7.9	372	28.5	50.0
24...	0950	9	8300	1000	--	8.0	372	28.5	--
24...	1000	9	8300	740.0	--	8.0	370	28.5	--
24...	1010	9	8300	480.0	--	8.0	367	28.5	--
24...	1020	9	8300	250.0	--	8.0	361	28.5	--
24...	1030	9	8300	--	--	8.0	370	28.5	--
24...	1035	9	8300	50.0	--	7.9	360	28.5	--
31...	0955	9	26300	--	9.8	7.8	292	28.0	30.0
31...	1025	9	26300	--	--	7.8	306	28.0	--
31...	1043	9	26300	25.0	--	7.9	310	27.5	--
AUG									
07...	1000	9	11400	--	9.8	7.6	318	28.0	65.0
07...	1020	9	11400	--	--	7.7	328	26.0	--
07...	1045	9	11400	20.0	--	7.7	328	28.0	--
08...	1000	9	11600	--	--	7.9	360	28.5	65.0
08...	1015	9	11600	--	--	8.0	345	28.5	--
08...	1040	9	11600	20.0	10.7	7.8	358	28.5	--
09...	0930	9	8110	--	9.5	7.9	368	31.5	65.0
09...	0950	9	8110	--	--	7.8	355	32.0	--
09...	0958	9	8110	40.0	--	7.7	348	31.0	--
10...	1005	9	8990	--	9.4	7.8	363	31.5	60.0
10...	1100	9	8990	--	--	7.7	353	31.5	--
10...	1110	9	8990	40.0	--	7.6	336	31.5	--
14...	0850	9	19600	--	9.2	7.2	365	20.5	40.0
14...	0910	9	19600	--	--	7.3	352	19.5	--
14...	0925	9	19600	40.0	--	7.4	351	19.5	--
21...	1235	9	6480	--	7.2	7.2	375	17.5	70.0
21...	1250	9	6480	--	--	7.4	367	17.5	--
21...	1305	9	6480	40.0	--	7.6	364	17.5	--
28...	0950	9	14300	--	10.7	6.7	390	27.0	50.0
28...	0956	9	14300	1010	--	6.9	387	27.0	--
28...	1010	9	14300	750.0	--	6.9	387	27.0	--
28...	1015	9	14300	--	--	6.9	387	27.0	--
28...	1020	9	14300	480.0	--	6.9	387	27.0	--
28...	1025	9	14300	250.0	--	6.9	387	27.0	--
28...	1035	9	14300	20.0	--	6.5	396	27.0	--
29...	0942	9	13000	--	10.9	7.3	361	30.0	30.0
29...	1000	9	13000	--	--	7.5	357	26.0	--
29...	1020	9	13000	60.0	--	7.6	347	30.5	--
30...	0915	9	9400	--	10.1	7.5	377	26.0	50.0
30...	0930	9	9400	--	--	7.6	372	26.0	--
30...	0940	9	9400	40.0	--	7.5	368	26.0	--
SEP									
04...	0955	9	9600	--	9.9	6.8	407	22.5	60.0
04...	1015	9	9600	--	--	7.0	392	26.0	--
04...	1025	9	9600	50.0	--	7.0	393	26.0	--
26...	0900	9	11500	--	8.8	7.6	455	21.0	50.0
26...	1010	9	11500	--	--	7.6	457	21.0	243
26...	1017	9	11500	--	--	7.6	457	21.0	453
26...	1021	9	11500	--	--	7.6	457	21.0	768
26...	1025	9	11500	--	--	7.6	457	21.0	1010
26...	1030	9	11500	--	--	7.6	457	21.0	--
26...	1040	9	11500	50.0	8.9	7.7	455	21.0	--
28...	0845	9	8380	--	9.3	7.8	427	20.0	30.0
28...	0930	9	8380	--	--	7.7	423	20.0	--
28...	1015	9	8380	20.0	9.5	7.9	423	20.0	--

03086000 OHIO RIVER AT SEWICKLEY, PA—Continued

WATER-QUALITY DATA, WATER YEAR OCTOBER 2000 TO SEPTEMBER 2001

DATE	MEDIUM CODE	SAMPLE LOC- ATION, CROSS SECTION (FT FM R BK) (72103)	TUR- BID- ITY (NTU) (00076)	E COLI, MTEC MF WATER (COL/ 100 ML) (31633)	ENTERO- COCCI, ME MF, WATER (COL/ 100 ML) (31649)	FECAL COLI- FORM, MFC MF, WATER (COL/ 100 ML) (31616)	SAMPLE LOC- ATION, CROSS SECTION (FT FM L BANK) (00009)
JUL							
12...	9	--	18	450	120	640	20.0
12...	9	--	25	280	45	700	--
12...	9	20.0	11	260	55	420	--
18...	9	--	11	160	140	200	50.0
18...	9	--	11	6	5	50	--
18...	9	35.0	6.8	45	<5	85	--
24...	9	--	7.6	300	200	230	50.0
24...	9	1000	8.9	15	<5	40	--
24...	9	740.0	10	40	<5	15	--
24...	9	480.0	13	90	15	120	--
24...	9	250.0	11	5	<5	15	--
24...	9	--	11	<5	10	20	--
24...	9	50.0	6.7	15	<5	15	--
31...	9	--	16	65	35	100	30.0
31...	9	--	32	20	<5	120	--
31...	9	25.0	11	160	60	200	--
AUG							
07...	9	--	9.9	75	25	100	65.0
07...	9	--	14	40	15	95	--
07...	9	20.0	10	45	10	100	--
08...	9	--	14	200	260	700	65.0
08...	9	--	26	1300	350	650	--
08...	9	20.0	15	760	540	590	--
09...	9	--	50	900	595	1600	65.0
09...	9	--	23	400	115	580	--
09...	9	40.0	17	520	25	960	--
10...	9	--	10	300	65	870	60.0
10...	9	--	15	420	70	250	--
10...	9	40.0	8.7	260	50	560	--
14...	9	--	9.4	460	15	560	40.0
14...	9	--	12	460	10	560	--
14...	9	40.0	6.4	500	20	660	--
21...	9	--	5.4	15	5	40	70.0
21...	9	--	9.6	10	5	25	--
21...	9	40.0	5.7	15	5	25	--
28...	9	--	12	130	55	420	50.0
28...	9	1010	--	110	20	130	--
28...	9	750.0	--	490	15	100	--
28...	9	--	13	240	10	760	--
28...	9	480.0	--	260	5	170	--
28...	9	250.0	--	140	5	220	--
28...	9	20.0	6.9	320	25	160	--
29...	9	--	40	100	705	3100	30.0
29...	9	--	37	2300	310	2200	--
29...	9	60.0	26	1400	400	1700	--
30...	9	--	19	40	65	890	50.0
30...	9	--	24	2300	180	770	--
30...	9	40.0	21	40	135	8	--
SEP							
04...	9	--	11	10	15	120	60.0
04...	9	--	14	100	<5	120	--
04...	9	50.0	9.7	80	5	100	--
26...	9	--	10	1900	35	2700	50.0
26...	9	--	--	600	15	2600	243
26...	9	--	--	440	10	420	453
26...	9	--	--	2100	50	4700	768
26...	9	--	--	2100	10	3100	1010
26...	9	--	13	2000	20	3200	--
26...	9	50.0	10	2200	30	3600	--
28...	9	--	11	120	5	240	30.0
28...	9	--	13	140	15	230	--
28...	9	20.0	12	3100	10	31000	--