

Concentrations of *Escherichia coli* in Streams in the Kankakee and Lower Wabash River Watersheds in Indiana, June-September 1999

Water-Resources Investigations Report 01-4018



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By Cheryl A. Silcox, Bret A. Robinson, and Timothy C. Willoughby

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Conversion Factors and Abbreviations

Multiply	By	To obtain
mile (mi)	1.609	kilometer
square mile (mi ²)	2.590	square kilometer
cubic foot per second (ft ³ /sec)	0.02832	cubic meter per second
pound per square inch (lb/in ²)	70.307	gram per square centimeter

Temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by use of the following equation:

$$^{\circ}\text{F} = 1.8(^{\circ}\text{C}) + 32$$

Abbreviated water-quality units used in this report: Chemical concentrations and water temperature are given in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in parts per million. Concentrations of bacteria are given in colonies per 100 milliliters (col/100 mL).

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

Volumes of water-quality samples are given in liters (L) and milliliters (mL).

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Abstract

Water samples collected from 58 surface-water sites in the Kankakee and Lower Wabash River Watersheds from June through September 1999 were analyzed for concentrations of *Escherichia coli* bacteria. Each site was sampled five times in a 30-day period. Twenty-nine sites were sampled during June and July, and 29 different sites were sampled during August and September. A five-sample geometric mean of concentrations was computed for each site. Concentrations of *Escherichia coli* (*E. coli*) in 126 of the 289 samples exceeded the State of Indiana single-sample standard of 235 colonies per 100 milliliters for waters used for recreation. Concentrations in samples from 38 of the 58 sites exceeded the State of Indiana standard for a five-sample geometric mean of 125 colonies per 100 milliliters for waters used for recreation.

Ten of the 58 sites were at or near U.S. Geological Survey streamflow-gaging stations. Based on records from the streamflow-gaging stations, 18 percent of the samples collected at these sites were collected at streamflows above the median daily discharge for each station.

E. coli concentrations and turbidity measurements collected during 1999 were analyzed

in concert with similar concentration and turbidity data collected in 1998 at streams within the Upper Wabash River Watershed in Indiana to investigate the relation between concentrations of bacteria and turbidity. The analysis indicated a statistically significant correlation between concentrations of *E. coli* and turbidity. If the turbidity was greater than 83 nephelometric turbidity units, the *E. coli* concentration always exceeded the single-sample standard. If, however, the turbidity was less than 83 nephelometric turbidity units, concentrations of *E. coli* were not always below the single-sample standard.

Introduction

The presence of *E. coli* in water is direct evidence of the presence of fecal contamination from warm-blooded animals and indicates the possible presence of pathogens (Myers and Sylvester, 1997). *E. coli* is one of the two preferred indicator bacteria used by the U.S. Environmental Protection Agency (USEPA) to determine the suitability of surface waters for recreational use. The water-quality standards for *E. coli* in recreational waters in Indiana require the concentration of *E. coli* to be less than the single-sample standard of 235 colonies per 100 mL (milliliters) and less than the geometric mean of 125 colonies per 100 mL computed from five samples collected within a 30-day period (Oddi, 1995).

The Indiana Department of Environmental Management (IDEM) is responsible for monitoring watersheds in Indiana and reporting the quality of the State's waters to Congress through the State's Report to Congress on Water Quality, 305B Report. As part of this statewide watershed assessment program, IDEM entered into a cooperative agreement with the U.S. Geological Survey (USGS) to measure concentrations of the bacteria *Escherichia coli* (*E. coli*) in the Upper Wabash River Watershed in 1998 (Silcox and others, 2000). Continuing the program in 1999, the USGS measured concentrations of *E. coli* at 58 surface-water sites in the Kankakee and Lower Wabash River Watersheds from June through September.

Purpose and Scope

This report documents the concentrations of *E. coli* measured in samples from selected streams in the Kankakee and Lower Wabash River Watersheds from June through September 1999. The report also discusses the relation between concentrations of *E. coli* and streamflow at sites where streamflow records were available and examines the relation between concentrations of *E. coli* and turbidity. Quality-assurance data for the *E. coli* samples are presented. Field measurements of water temperature, pH, dissolved oxygen, specific conductance, and turbidity collected at the same time as the samples analyzed for *E. coli* also are presented.

Description of the Study Area

Samples were collected in the Kankakee River and Lower Wabash River Watersheds (fig. 1). Within the Kankakee River Watershed, samples were collected from the Indiana-Illinois state line upstream to sites east and north of Plymouth, Ind. The Kankakee River Watershed drains 1,920 mi² (Hoggatt, 1975) in Indiana. Major tributaries to the Kankakee River from which samples were collected include the Little Kankakee River, Pine Creek, Singleton Ditch, the Yellow River, and the Iroquois River. Within the Iroquois River Water-

shed, which discharges to the Kankakee River in Illinois, samples were collected from 5 mi east of the Indiana-Illinois state line upstream to sites east of Rensselaer, Ind. This watershed drains 661 mi² in Indiana.

The remaining samples were collected from the Lower Wabash River Watershed, which, for the purposes of this study, extends from Lafayette, Ind., to that point at which the Wabash River discharges to the Ohio River in southwestern Indiana. Major tributaries to the lower Wabash River from which samples were collected include Big Pine Creek, Coal Creek, Sugar Creek, and Big Raccoon Creek. At its mouth, the Wabash River drains 23,921 mi² in Indiana.

The study area falls within three distinct physiographic areas (Schneider, 1966) and can be divided roughly into thirds. The northern third of the study area, including the Kankakee River and the Iroquois River Watersheds, falls within the Northern Moraine and Lake Region. This region includes broad moraines composed of glacial till and expansive valleys underlain by thick and topographically subdued sand deposits.

The middle third of the study area, from southern White and Benton Counties in the north to northern Vigo County in the south, falls within the Tipton Till Plain physiographic unit. This physiographic unit is nearly flat in most areas and shows appreciable relief only where river valleys, like the Wabash, have dissected the till plain.

The southern third of the study area, from Terre Haute to the mouth of the Wabash River, is entirely within the Wabash Lowland physiographic unit. In this area, the Wabash River Valley is broad and underlain by thick glacial-outwash deposits. Uplands are described as undulating to rolling and typically stand 100 to 150 ft above the adjacent valley floors (Schneider, 1966).

Study Methods

Selection of the sampling sites, the procedures used to collect the samples to meet a 6-hour sample-holding time limit, and the methods used to measure field parameters are described. Methods

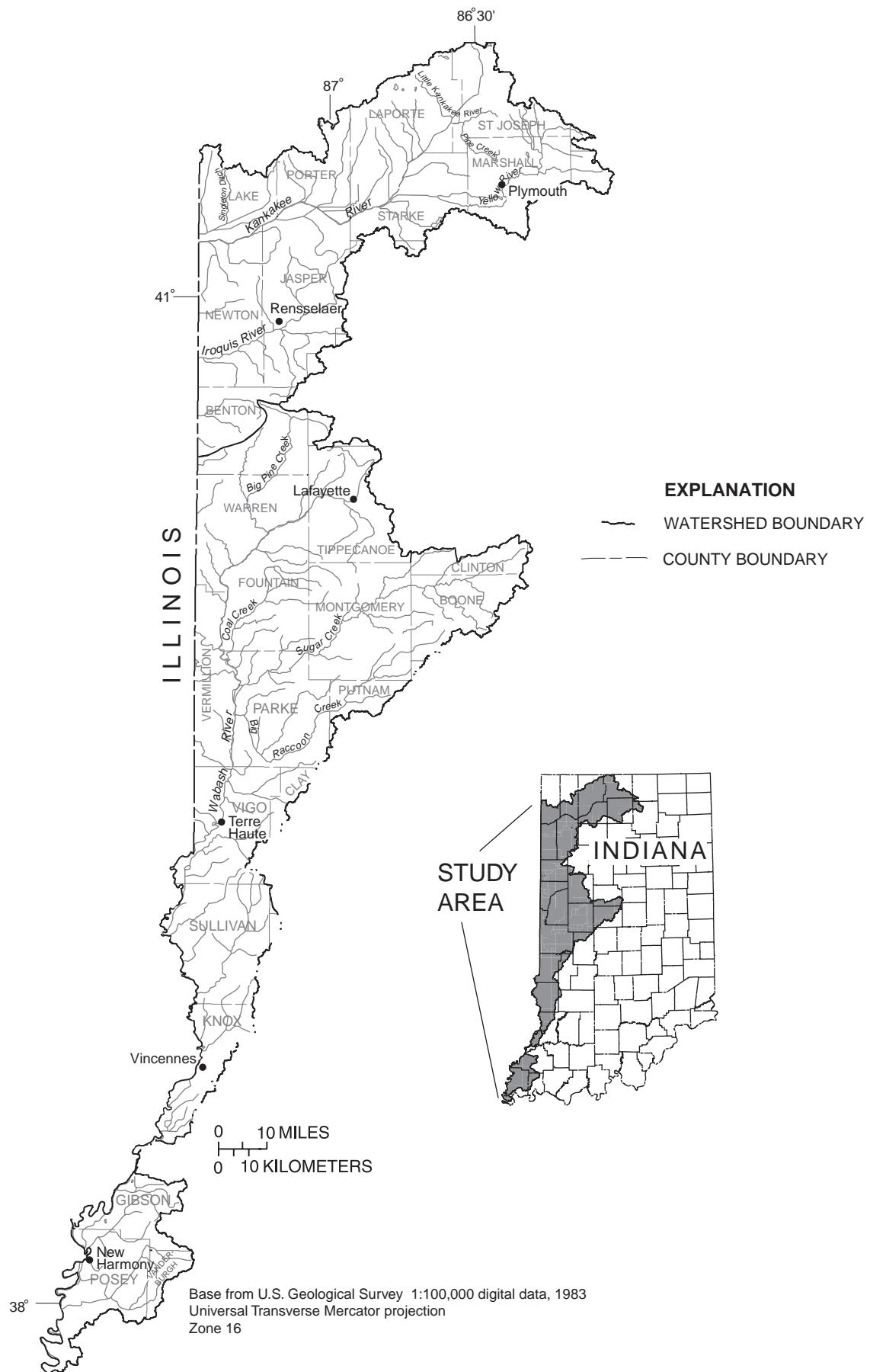


Figure 1. Location and principal streams of the Kankakee and Lower Wabash River Watersheds in Indiana.

used to collect and process the *E. coli* samples and the equation used to calculate the geometric mean are discussed. Statistical methods used to evaluate the relation between concentrations of *E. coli* and turbidity also are outlined.

Selection of Sampling Sites

Sampling sites initially were selected by IDEM personnel. Responses from a 1987 poll of local health officials, conservation officers, and sheriff's departments regarding known areas of stream recreational uses provided a core list of potential sampling sites. Additional sites were added to improve spatial coverage or to position sites at existing USGS streamflow-gaging stations. Site locations were verified on topographic maps and field verified by USGS personnel prior to sample collection. Where sampling conditions were unsafe or where site characteristics interfered with the ability to collect a sample, the site was relocated as close to the initial site as possible. Changes to sampling-site locations were agreed upon by USGS and IDEM personnel.

The 58 selected sampling sites were divided into two groups so that all sites could be sampled five times at equally spaced intervals within a 30-day period. Figure 2 shows the locations of the sampling sites. Table 1 lists the Group 1 sites (sites 1 through 25, 30, 33, 41, and 42) that were sampled during June and July 1999. Most of the Group 1 sites were in the Kankakee River Watershed. Table 2 lists the Group 2 sites (sites 26 through 29, 31, 32, 34 through 40, and 43 through 58) that were sampled during August and September 1999. All of the Group 2 sites were in the Lower Wabash River Watershed.

Field Measurements

At each sampling site, a multi-parameter water-quality probe was used to make field measurements of water temperature, dissolved oxygen, pH, and specific conductance at several locations across the width of the stream. The probes used

to measure dissolved oxygen, pH, and specific conductance were calibrated daily.

Field determinations of turbidity were made by collecting samples of stream water in polyethylene bottles and analyzing the samples with a portable turbidimeter. The measuring range of the turbidimeter was checked daily with reference standards. Water temperature, dissolved-oxygen concentration, pH, specific conductance, and turbidity were measured at the same locations in the stream where the samples were collected for analysis of *E. coli*.

Collection of Samples

Water samples were collected during the recreational season in Indiana, defined as April through October. The samples were collected by two-person field crews in order to expedite the sampling process and to meet the mandated 6-hour sample-holding time limit prior to processing the samples. Duties at the sampling sites included

- measuring and recording field parameters,
- measuring and recording water-surface-elevation data by using a measuring tape lowered to the surface of the stream from the top of the bridge or
- documenting the stage levels of streams at sites where streamflow-gaging stations were present or nearby, and
- collecting the water samples for analysis of *E. coli*.

At the time of sampling, the characteristics of stage change, water clarity, and weather conditions also were recorded on the field forms.

Water samples for *E. coli* determinations were collected in 300 mL (milliliter) glass bottles with glass stoppers. Prior to use, the bottles were washed with detergent, rinsed three times with tap water and three times with deionized water, and sterilized by autoclaving. To ensure optimum growth conditions for *E. coli*, two solutions were added to each sample bottle before the bottle was sterilized. To counter the effects of residual chlorine or other halogens used in water-disinfection pro-

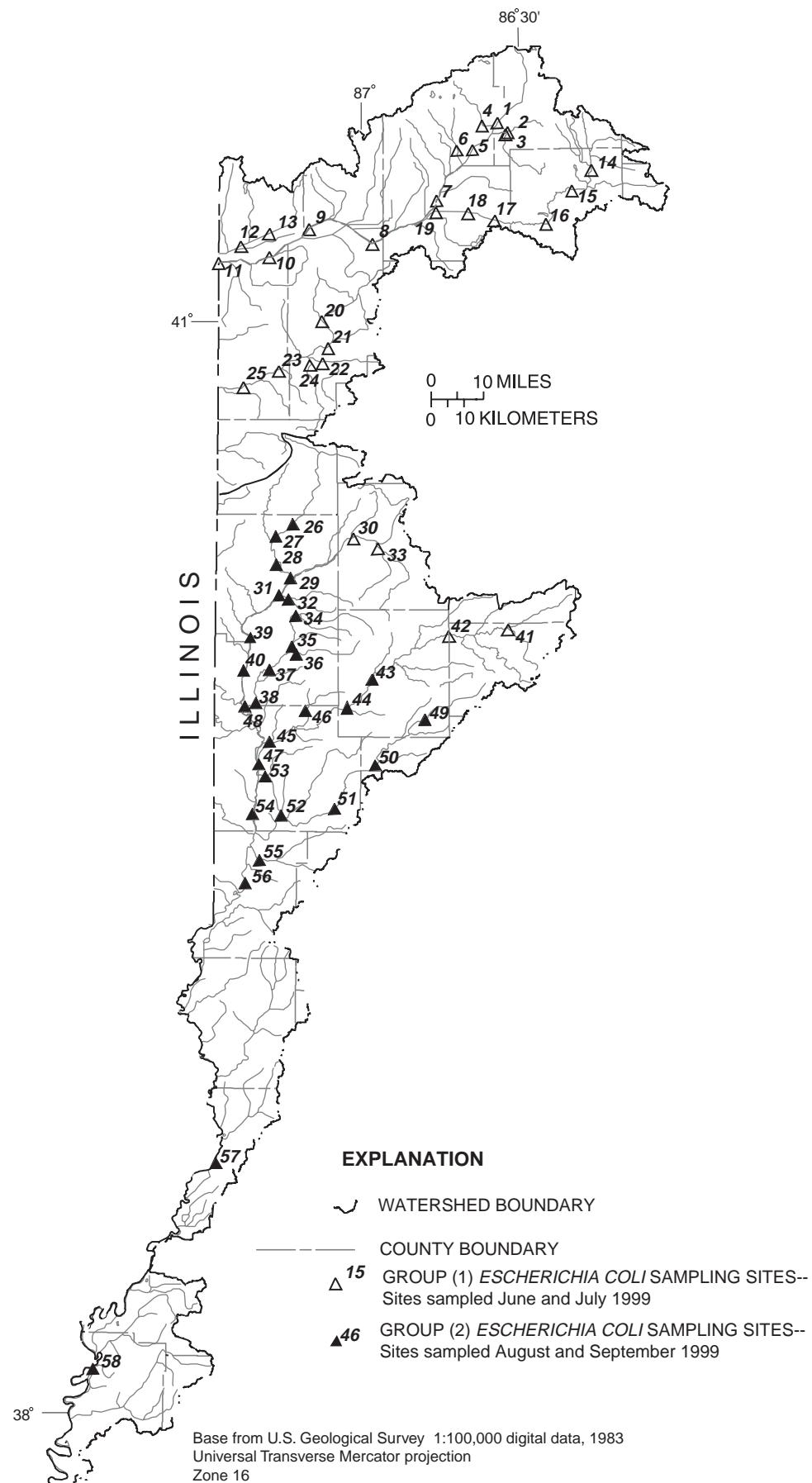


Figure 2. Location of *Escherichia coli* sampling sites in the Kankakee and Lower Wabash River Watersheds in Indiana.

Table 1. Sites in the Kankakee and Lower Wabash River Watersheds in Indiana at which water samples were collected during June and July 1999 (Group 1 sites) for analysis of *Escherichia coli*

[USGS, U.S. Geological Survey; SR, State Road; CR, County Road; US, U.S. Highway; E, N, and S, denote the geographic directions of east, north, and south]

Site number	Site location	USGS site identification	Latitude and longitude	County
1	Kankakee River at SR 4 near North Liberty	413301086304201	41° 33' 01" 86° 30' 42"	Laporte
2	Potato Creek at Walnut Road near North Liberty	413127086283701	41° 31' 27" 86° 28' 37"	St. Joseph
3	Pine Creek at Quinn Road near North Liberty	413111086285501	41° 31' 11" 86° 28' 55"	St. Joseph
4	Little Kankakee River at CR 700E near Stillwell	413236086340601	41° 32' 36" 86° 34' 06"	Laporte
5	Kankakee River at US 6 near South Center	412839086361601	41° 28' 39" 86° 36' 16"	Laporte
6	Travis Ditch at US 6 near South Center	412834086393901	41° 28' 34" 86° 39' 39"	Laporte
7	Kankakee River at SR 39 near Brems	412019086440601	41° 20' 19" 86° 44' 06"	Laporte
8	Kankakee River at Dunns Bridge	05517500	41° 13' 11" 86° 58' 05"	Jasper
9	Kankakee River at US 231 near Demotte	411535087115601	41° 15' 35" 87° 11' 56"	Porter
10	Kankakee River at Shelby	05518000	41° 10' 57" 87° 20' 26"	Lake
11	Kankakee River at CR 700 near Illiana Heights, Ill.	410958087313501	41° 09' 58" 87° 31' 35"	Newton
12	Singleton Ditch at Schneider	05519000	41° 12' 44" 87° 26' 54"	Lake
13	Singleton Ditch at SR 55 near Shelby	411449087203701	41° 14' 49" 87° 20' 37"	Lake
14	Yellow River near Bremen	05516000	41° 25' 11" 86° 10' 14"	Marshall
15	Yellow River at N Jarrah Road near Plymouth	412147086143101	41° 21' 47" 86° 14' 31"	Marshall
16	Yellow River at South Olive Trail near Plymouth	411622086201501	41° 16' 22" 86° 20' 15"	Marshall
17	Yellow River at SR 23 near Ober	411659086312801	41° 16' 59" 86° 31' 28"	Starke
18	Yellow River at Knox	05517000	41° 18' 10" 86° 37' 14"	Starke
19	Yellow River at SR 39 near Knox	411823086441401	41° 18' 23" 86° 44' 14"	Starke
20	Iroquois River at US 231 near Rensselaer	410027087090501	41° 00' 27" 87° 09' 05"	Jasper
21	Iroquois River at Rensselaer	05522500	40° 56' 01" 87° 07' 43"	Jasper
22	Slough Creek near Collegeville	05523500	40° 53' 30" 87° 09' 17"	Jasper
23	Iroquois River near Foresman	05524500	40° 52' 13" 87° 18' 23"	Newton
24	Carpenter Creek at CR 850S near Egypt	405317087112201	40° 53' 17" 87° 11' 22"	Jasper
25	Iroquois River at US 41 near Kentland	404933087260501	40° 49' 33" 87° 26' 05"	Newton
30	Wabash River near West Point	03335680	40° 24' 43" 87° 02' 11"	Tippecanoe
33	Wea Creek at CR 200S near Lafayette	402305086570101	40° 23' 05" 86° 57' 01"	Tippecanoe
41	Sugar Creek at SR 39 at Mechanicsburg	400942086290801	40° 09' 42" 86° 29' 08"	Boone
42	Sugar Creek at County Line Road near Thorntown	400836086414501	40° 08' 36" 86° 41' 45"	Boone

Table 2. Sites in the Lower Wabash River Watershed in Indiana at which water samples were collected during August and September 1999 (Group 2 sites) for analysis of *Escherichia coli*

[USGS, U.S. Geological Survey; SR, State Road; CR, County Road; US, U.S. Highway; I-64, Interstate 64; E, W, and N, denote the geographic directions of east, west, and north]

Site number	Site location	USGS site identification	Latitude and longitude	County
26	Big Pine Creek at SR 55 at Pine Village	402708087151601	40° 27' 08" 87° 15' 16"	Warren
27	Big Pine Creek at CR 025E at Rainsville	402505087185601	40° 25' 05" 87° 18' 56"	Warren
28	Big Pine Creek at CR 100E near Kramer	402025087185101	40° 20' 25" 87° 18' 51"	Warren
29	Big Pine Creek at SR 55 at Attica	401814087154701	40° 18' 14" 87° 15' 47"	Warren
31	Wabash River at Shawnee Bridge near Williamsport	401518087175901	40° 15' 18" 87° 17' 59"	Fountain
32	Big Shawnee Creek at CR 70W near Rob Roy	401448087162701	40° 14' 48" 87° 16' 27"	Fountain
34	Coal Creek at US 41 at Aylesworth	401200087143501	40° 12' 00" 87° 14' 35"	Fountain
35	Coal Creek at US 136 at Veedersburg	400647087152001	40° 06' 47" 87° 15' 20"	Fountain
36	East Fork Coal Creek at US 41 near Veedersburg	400549087143401	40° 05' 49" 87° 14' 34"	Fountain
37	Coal Creek at SR 32 near Perrysville	400306087201601	40° 03' 06" 87° 20' 16"	Fountain
38	Coal Creek at SR 234 near Silverwood	395735087232201	39° 57' 35" 87° 23' 22"	Fountain
39	Wabash River at Covington	03336000	40° 08' 26" 87° 24' 21"	Warren
40	Wabash River at SR 32 at Perrysville	400259087254501	40° 02' 59" 87° 25' 45"	Fountain
43	Sugar Creek at SR 32 at Yountsville	400131086581601	40° 01' 32" 86° 58' 17"	Montgomery
44	Sugar Creek at Deer Mill Bridge near Alamo	395646087033001	39° 56' 46" 87° 03' 31"	Montgomery
45	Sugar Creek at CR 525W at West Union	395117087201001	39° 51' 17" 87° 20' 10"	Parke
46	Sugar Mill Creek at CR 1260N near Grange Corner	395623087123001	39° 56' 23" 87° 12' 30"	Parke
47	Wabash River at Montezuma	03340500	39° 47' 32" 87° 22' 29"	Parke
48	Wabash River at SR 234 near Lodi	395708087251201	39° 57' 08" 87° 25' 12"	Vermillion
49	Big Raccoon Creek at SR 234 at Ladoga	395456086465801	39° 54' 56" 86° 46' 58"	Montgomery
50	Big Raccoon Creek at CR 790N near Morton	394725086573201	39° 47' 25" 86° 57' 32"	Putnam
51	Big Raccoon Creek at SR 59 at Mansfield	394015087061701	39° 40' 15" 87° 06' 17"	Parke
52	Big Raccoon Creek at Coxville	03341300	39° 39' 09" 87° 17' 37"	Parke
53	Big Raccoon Creek at CR 600W at Armiesburg	394533087210401	39° 45' 33" 87° 21' 04"	Parke
54	Wabash River at SR 163 at Clinton	393923087234301	39° 39' 23" 87° 23' 43"	Vermillion
55	Otter Creek at Lafayette Avenue at Terre Haute	393147087221201	39° 31' 47" 87° 22' 12"	Vigo
56	Wabash River at US 40W at Terre Haute	392759087251301	39° 27' 59" 87° 25' 13"	Vigo
57	Wabash River at Lincoln Memorial Bridge at Vincennes	384156087310701	38° 40' 53" 87° 32' 07"	Knox
58	Wabash River at I-64 near Griffin	381342087590400	38° 13' 42" 87° 59' 04"	Posey

cesses, 0.3 mL of a 10-percent solution of sodium thiosulfate was added to the bottles. Residual chlorine and other halogen compounds act as bacterial-growth inhibitors; their effects need to be reduced so that *E. coli* can fully recover on the growth medium and produce accurate counts (Bordner and Winter, 1978; American Public Health Association and others, 1992). In addition, 0.9 mL of a 15-percent solution of ethylenediaminetetraacetic acid (EDTA) was added to neutralize the effects of trace-element concentrations greater than 10 $\mu\text{g/L}$ (micrograms per liter). EDTA, a chelating agent, binds particularly with copper and zinc, making the metals neutral so that they do not adversely affect bacterial growth (Britton and Greeson, 1989, p. 5–6; Bordner and Winter, 1978; American Public Health Association and others, 1992).

In the field, a weighted hand-line sampler that held the sample bottle was lowered beneath the surface of the water. Some samples were collected by immersing the bottles by hand when the stream was too shallow for the hand-line sampler. At each site, the sample was a composite of water from one to six well-mixed areas of flow, depending on the width of the stream. The samples were kept on ice until processed. Duplicate samples were collected concurrently with the environmental samples at selected sites.

Processing of Samples

Equipment used to process the samples was washed with detergent prior to field work, rinsed three times with hot tap water and three times with deionized water, and then sterilized with an 8-watt ultraviolet (UV) lamp having a wavelength of 254 nanometers for a minimum of 15 minutes. Processing equipment included a multi-port manifold filter stand, stainless-steel filter holders, vacuum pumps, sterile disposable pipets, and glass graduated cylinders. After the samples were processed, aluminum-block incubators were used to provide optimum conditions for bacterial growth.

The USGS Ohio District Microbiological Laboratory prepared and provided fresh

membrane-filter Thermotolerant (mTec) agar on which the *E. coli* were grown. The fresh mTec agar was poured into petri dishes in the USGS Indiana District laboratory for use in the field. Refrigeration units were used to keep the mTec agar chilled before being used. The 2-week holding time for mTec agar, once it was prepared, was monitored in the laboratory and field. Urea/phenol red reagent was obtained from the USGS Quality of Water Services Unit (QWSU), prepared in the field, and used to confirm the presence of *E. coli* colonies.

The samples collected for analysis of *E. coli* were processed either in hotel rooms or in the USGS Indiana District laboratory. Surfaces on which the samples were processed were cleaned with isopropyl alcohol before the first sample was processed, between samples, and after the last sample was processed each day. Analysts washed their hands with bactericidal soap before processing the first sample, between samples, and after processing the last sample.

Five to eight different sample volumes, including one to three different dilutions, were filtered for each site because the extent of possible *E. coli* contamination was unknown at each site. A range of small to large sample volumes and dilutions was used for processing. This was done to obtain at least one sample volume capable of producing one or more filter plates with sufficient colony growth to obtain an ideal *E. coli* colony count of 20 to 80 colonies per filter plate (Myers and Sylvester, 1997). Stream conditions at the time of each sampling and previous colony counts for each site obtained after the first week of sampling guided the analysts in determining the quantity and types of sample volumes to process to obtain one or more filter plates in an ideal range. Sample dilutions were made by adding 11 mL of sample water to 99 mL of sterile dilution water for a 1:10 ratio and 1 mL of sample water to another 99 mL of sterile dilution water for a 1:100 ratio.

Samples were shaken vigorously before each sample dilution volume was withdrawn to ensure uniform distribution of the bacteria throughout the sample. Sterile, disposable 1-mL and 10-mL glass pipets were used to measure and deliver concentrated sample volumes to dilution bottles and to

measure and deliver dilution volumes to the interior of the funnel filter assembly. For sample dilution volumes less than 10 mL, about 20 mL of sterile saline buffer solution was poured into the funnel before pipetting the sample dilution to evenly distribute the bacteria on the filter. A sterile graduated cylinder was used to transfer sample dilution volumes greater than 10 mL. A three-port manifold with funnels or a single-use stainless-steel-filter system was used to support a 0.45- μ m (micron) filter designed to facilitate colony capture, incubation, and quantification. The water was pulled through the filter either by a vacuum pump set not to exceed 5 lb/in² or by a hand vacuum assembly.

After filtering each of the sample dilution volumes, 20 to 30 mL of sterile saline buffer solution were used to flush the sides of the funnel to ensure that any bacteria present on the funnel walls were rinsed on to the filter. The graduated cylinders used to measure and deliver sample dilution volumes to the funnel also were rinsed with sterile saline buffer solution, and the rinsate was processed through the filter.

Petri dishes containing the mTec agar used to encourage growth of *E. coli* colonies on the prepared filters were labeled prior to processing the sample. Undiluted (environmental) samples and sample dilutions were filtered from smallest to largest. The filters then were placed in petri dishes with the mTec agar and placed inverted in a preheated incubator set at 35.0°C for 1.75 to 2 hours, removed, and then placed in a preheated incubator set at 44.5°C for 22 to 24 hours. After the second incubation period was completed, the filter was transferred to a filter pad saturated with urea/phenol red reagent. After 15 to 20 minutes at room temperature, the yellow to yellow-brown *E. coli* colonies were counted. If the filter plate had a colony count in the ideal range, verification of the count was made either by the second crew member or by rotating the filter 90 degrees and recounting the colonies. Concentrations of *E. coli* were calculated according to the methods described by (Myers and Sylvester, 1997, p. 31–33-FIB) and recorded on the field sheet. If more than one dilution were within the ideal colony count, the concentration of *E. coli* was computed as the sum of the colony counts for

each sample volume multiplied by 100 and divided by the sum of the sample volumes. For example, if 24 colonies were counted for a sample volume of 3 ml and 60 colonies were counted for a sample volume of 10 ml, the concentration of *E. coli* is calculated as follows:

$$\text{Col}/100 \text{ mL} = (24 + 60) \times 100/(3 + 10) = 646 \quad (1)$$

where:

$\text{Col}/100 \text{ mL}$ = colonies per 100 milliliters;

24 + 60 are the colony counts on two different filter plates;

3 + 10 are the sample volumes filtered for each plate.

Reporting whole numbers as two significant figures for results greater than or equal to 10 resulted in a reporting value of 650 colonies per 100 mL. The same calculation was used if *E. coli* colonies were present but none of the dilutions had concentrations of *E. coli* within the ideal colony count. In these cases, all dilutions having colonies present were used in the calculation and reported as an estimate (denoted with a “K”). If no *E. coli* colonies were present, a value of one colony was assigned to the largest sample volume filtered and the same calculation method was used. These calculations, using one colony for the largest sample volume filtered, were reported as the calculated number preceded by a less than symbol. Colony counts were recorded on field sheets labeled for each site. Concentrations of *E. coli* were reported in whole numbers for results less than 10, and results greater than or equal to 10 were reported in two significant figures (Myers and Sylvester, 1997, p. 30-FIB). After counting the number of colonies, petri dishes were filled with chlorine bleach, placed in sealed plastic bags, and discarded.

Geometric Mean

The five-sample geometric mean was calculated, using equation 2.

$$GM = \sqrt[5]{S_1 \cdot S_2 \cdot S_3 \cdot S_4 \cdot S_5} \quad (2)$$

where:

GM is the geometric mean, and

S_i is the concentration of *E. coli* measured in each of the five samples.

One field form was lost before the *E. coli* concentration could be entered into the data base for site 16. The sample was collected on June 30, 1999. To compute the five-sample geometric mean for this site, the value of one colony per 100 mL was substituted for the lost *E. coli* concentration. If the five-sample geometric mean exceeded the standard after the substitution was made, which it did, any value selected for substitution would have produced a five-sample geometric mean that exceeded the standard.

Statistical Analysis

A Wilcoxon signed-rank test (Helsel and Hirsch, 1992, p.142) was used to determine if there were statistically significant differences between the environmental samples and the concurrent duplicates. The Wilcoxon signed-rank test measured whether one group of data produced larger observations than the second group and made no assumptions regarding how the data were distributed (Helsel and Hirsch, 1992, p.118).

A Kendall's Tau test (Helsel and Hirsch, 1992, p. 212) for significant correlation was used to determine if there was a statistically significant correlation between the concentration of *E. coli* and turbidity. For this report, a five-percent level of significance ($\alpha=0.05$) was identified as the criterion for the statistical correlation. The p-value is derived from the data and measures the believability of the null hypothesis (no correlation exists between concentrations of *E. coli* and turbidity). The smaller the p-value, the more likely there is a correlation between concentrations of *E. coli* and turbidity and the stronger the evidence for rejection of the null hypothesis.

Quality-Assurance and Quality-Control Procedures

Quality-assurance and quality-control procedures were followed for collection and processing of the samples. These procedures include frequent checking and calibration of equipment as well as collection of additional samples for quality control.

Analysis of the quality-control samples provides quantitative information not only about the potential for sample contamination during collection and processing but also about the variability of sampling.

The pH buffers and specific-conductance solutions used to calibrate the multi-parameter probe were quality assured by the QWSU. The multi-parameter water-quality measuring meter was calibrated daily for pH, specific conductance, and dissolved oxygen before any field measurements were made. The measuring range of the portable turbidimeter used to measure turbidity in the surface-water samples was checked daily with reference standards. If parameters measured in the field were not stable or if they did not have reasonable values, the meters were recalibrated at the site and field parameters were remeasured.

E. coli fresh substrate media kits were quality assured by the USGS Ohio District Microbiological Laboratory. Membrane filters, sterile saline buffer solution, premeasured sterile dilution water, petri dishes, and petri dishes with pads also were quality assured by the QWSU. The incubators were checked weekly with an American Society for Testing and Materials (ASTM) certified thermometer to assure that temperature ranges shown on the internal thermometer in the incubator were accurate to $\pm 0.5^{\circ}\text{C}$. The incubators were inspected daily to assure they were operating properly.

Quality-control samples consisted of 289 filter blanks, 71 process blanks, 19 field blanks, and 39 duplicate samples. Results of the quality-assurance and *E. coli* determinations are presented in tables 3 and 4 at the back of this report. Blanks and duplicate samples are discussed separately.

Filter Blanks

Filter blanks were processed before every set of samples to determine if the equipment used to process the samples was clean and the saline buffer solution used to rinse sample-processing equipment was not contaminated. Filter blanks were processed for all 289 samples collected and were acquired by passing 100 ml of the sterile saline buffer solution

through the filter prior to processing any dilutions of the environmental samples. While passing the saline buffer solution through the filter, every attempt was made to have the saline buffer solution come in contact with every surface that the environmental sample might touch. One filter blank for site 58 had eight observable *E. coli* colonies. The presence of the colonies on the filter blank indicates that the sample-processing glassware had been contaminated, the saline buffer solution used for the sample set was contaminated, or the analyst made a procedural error. The results for site 58 are not greatly affected, however, because the *E. coli* concentration for that sample was very low and below the ideal colony-count range, resulting in the data being flagged as estimated.

Process Blanks

Process blanks consisted of 100 mL of saline buffer solution filtered through the same equipment used to process samples, ensuring the equipment rinses that followed the filtering of each sample were adequate. Process blanks were filtered for one sample daily. Sixteen of the 71 process blanks contained observable *E. coli* colonies. The maximum concentration of *E. coli* measured in the process blanks was seven colonies per 100 mL. All of the process blanks that had observable *E. coli* colonies contained less than 1 percent of the concentration of *E. coli* measured in the environmental samples; therefore, the sample results were not affected and nothing was done to modify the data.

Field Blanks

Nineteen field blanks were filtered during the length of the study on randomly selected days determined by the analysts. Field blanks consisted of 250 mL of sterile saline buffer solution that was poured into a sample-collection bottle. The field blanks were kept chilled and remained with the samples collected at all sites for that day. The field blanks were processed by passing 100 mL of the blank solution through the filter. None of the 19 field blanks had observable *E. coli* colonies, indicating that there was no contamination resulting

from transporting the samples and that there was adequate sterilization of the sample-collection bottles.

Duplicate Samples

Duplicate samples were collected concurrently with the environmental samples at selected sites. The concurrent duplicates were processed in the same manner as the environmental samples and were used to evaluate the natural variability in the samples.

Figure 3 displays the differences between concentrations of *E. coli* measured in the environmental samples and duplicate samples and the natural log percent difference between the two. The median natural log percent difference between the environmental samples and the duplicate samples was 8 percent. No statistically significant differences between the environmental samples and the concurrent duplicate samples were determined at the 5-percent significance level. The significance level obtained by the data, or the p-value (Helsel and Hirsch, 1992, p.112), was 0.623.

Concentrations of *Escherichia coli*

The Indiana environmental rules establish the bacteriological quality standard for waters for recreational uses (Oddi, 1995). These rules are used to evaluate waters for full-body-contact recreational uses, to establish wastewater-treatment requirements, and to establish effluent limits during the recreational season. The standard states:

E. coli bacteria, using membrane filter (MF) count, shall not exceed one hundred twenty-five (125) per one hundred (100) milliliters as a geometric mean based on not less than five (5) samples equally spaced over a thirty (30) day period nor exceed two hundred thirty-five (235) per one hundred (100) milliliters in any one (1) sample in a thirty (30) day period.

Table 3, at the back of the report, lists field measurements and concentrations of *E. coli* for

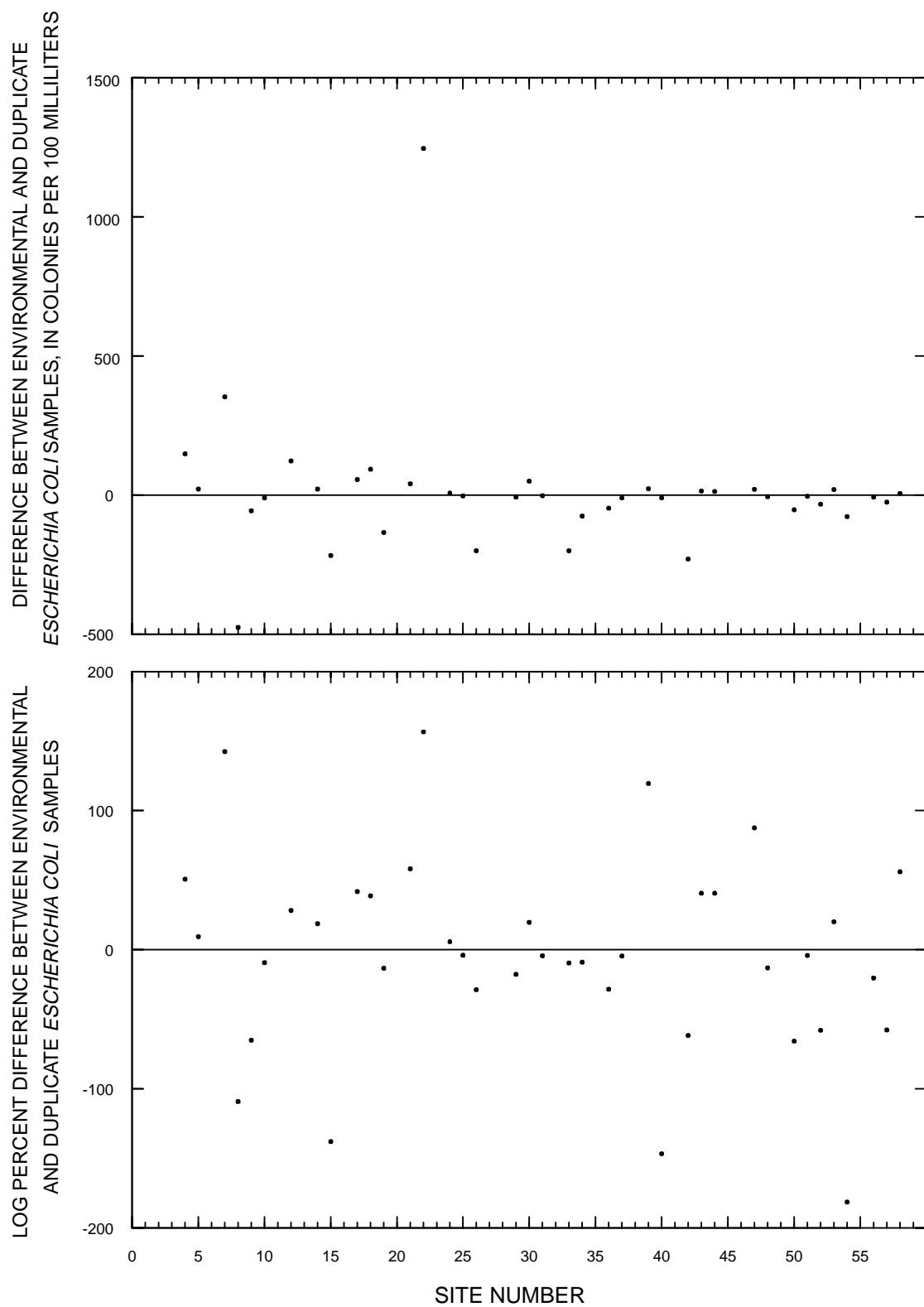


Figure 3. Concentrations of *Escherichia coli* measured in the environmental samples and duplicate samples and the natural log percent difference. Samples were collected in the Kankakee and Lower Wabash River Watersheds in Indiana, June–September 1999.

all 58 sites. The five-sample geometric mean is shown below the last sample-collection date for each site. Figure 4 shows the range in concentrations of *E. coli* for the five samples collected at each site, and figure 5 shows the five-sample geometric-mean concentration of *E. coli* determined for each site.

Concentrations of *E. coli* at all 58 sites ranged from less than 1 to greater than 8,000 colonies per 100 mL, with concentrations in 126 of the 289 samples processed exceeding the single-sample standard in samples from 40 sites. The five-sample geometric mean of concentrations of *E. coli* for all sites ranged from 4 to 1,400 colonies per 100 mL. The concentrations of *E. coli* in samples from 38 sites exceeded the five-sample geometric-mean standard.

Concentrations of *E. coli* were examined relative to their location at sampling sites along several stream reaches in the Kankakee and Lower Wabash River Watersheds (figs. 6 and 7). Stream reaches included the Kankakee, Yellow, and Iroquois Rivers in the Kankakee River Watershed and the Big Pine, Sugar, Big Raccoon, and Coal Creeks and the Wabash River in the Wabash River Watershed. Fifty-three of 85 samples from 17 sites on the Kankakee, Yellow, and Iroquois Rivers had concentrations of *E. coli* that exceeded the single-sample standard. Concentrations of *E. coli* exceeded the standard for the five-sample geometric mean at all sites (fig. 6).

Twenty of 35 samples from all seven sites (1, 5, and 7–11) on the Kankakee River had concentrations of *E. coli* that exceeded the single-sample standard. Concentrations of *E. coli* in samples from the Kankakee River ranged from 32 to 2,100 colonies per 100 mL. The five-sample geometric means ranged from 150 to 370 colonies per 100 mL.

Twenty-one of 29 samples from all six sites (14–19) on the Yellow River had concentrations of *E. coli* that exceeded the single-sample standard. Concentrations of *E. coli* in samples from the Yellow River ranged from 73 to 5,100 colonies per 100 mL. The five-sample geometric means ranged from 190 to 1,400 colonies per 100 mL.

Twelve of 20 samples from four sites (20, 21, 23, and 25) on the Iroquois River exceeded the single-sample standard. Concentrations of *E. coli* in samples from the Iroquois River ranged from less than 5 to 3,600 colonies per 100 mL. The five-sample geometric means ranged from 160 to 1,100 colonies per 100 mL.

Eight sites having only one or two sampling locations on a particular stream are shown as “other sites in the Kankakee River Watershed” (fig. 6). Thirty-one of 40 samples collected from these eight sites had concentrations of *E. coli* that exceeded the single-sample standard, and all sites exceeded the five-sample geometric mean. Concentrations of *E. coli* in these samples ranged from an estimated 65 to greater than 8,000 colonies per 100 mL. The five-sample geometric means ranged from 370 to 770 colonies per 100 mL.

Twenty-six of 55 samples from 11 sites on Big Pine, Sugar, Big Raccoon, and Coal Creeks and the Wabash River had concentrations that exceeded the single-sample standard, and seven of the sites exceeded the standard for the five-sample geometric mean (fig. 7). Five of 10 samples from two sites (26 and 28) on Big Pine Creek had concentrations of *E. coli* that exceeded the single-sample standard, and site 26 exceeded the standard for the five-sample geometric mean. All 10 samples from two sites on Big Pine Creek (27 and 29) had concentrations that did not exceed the single-sample standard; however, the five-sample geometric-mean standard was exceeded at site 27. Concentrations of *E. coli* in samples from Big Pine Creek ranged from 17 to 700 colonies per 100 mL. The five-sample geometric means ranged from 29 to 400 colonies per 100 mL.

Three of 10 samples from two sites (41 and 42) on Sugar Creek had concentrations of *E. coli* that exceeded the single-sample standard. Both of these sites exceeded the standard for the five-sample geometric mean. Samples from sites 43 through 45 on Sugar Creek did not exceed either standard. Concentrations of *E. coli* in samples from Sugar Creek ranged from 7 to 1,500 colonies per 100 mL, and the five-sample geometric means ranged from 29 to 280 colonies per 100 mL.

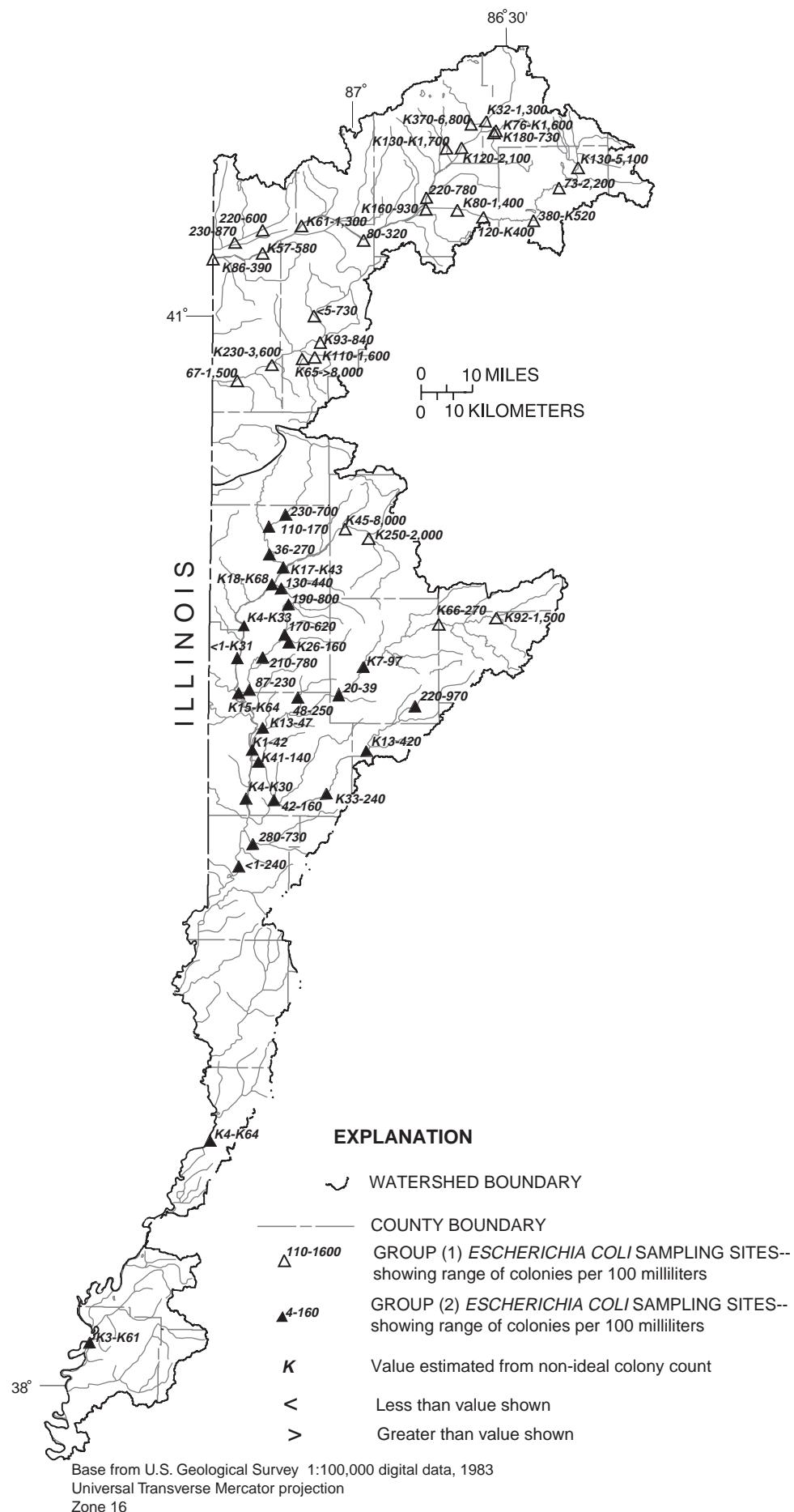


Figure 4. Ranges in concentrations of *Escherichia coli* for sampling sites in the Kankakee and Lower Wabash River Watersheds in Indiana, June through September 1999.

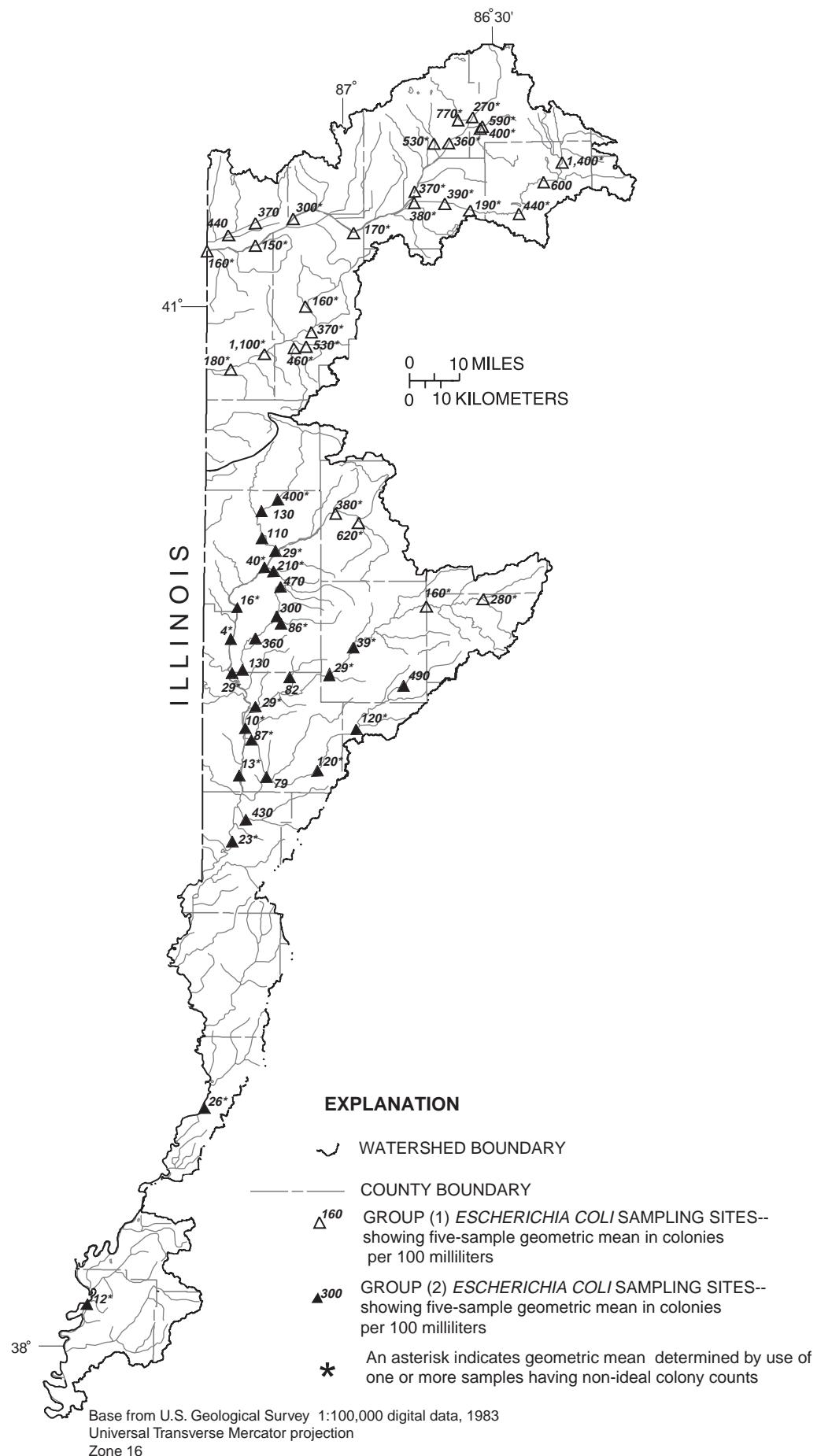


Figure 5. Five-sample geometric mean *Escherichia coli* concentration determined for sampling sites in the Kankakee and Lower Wabash River Watersheds in Indiana, June-September 1999.

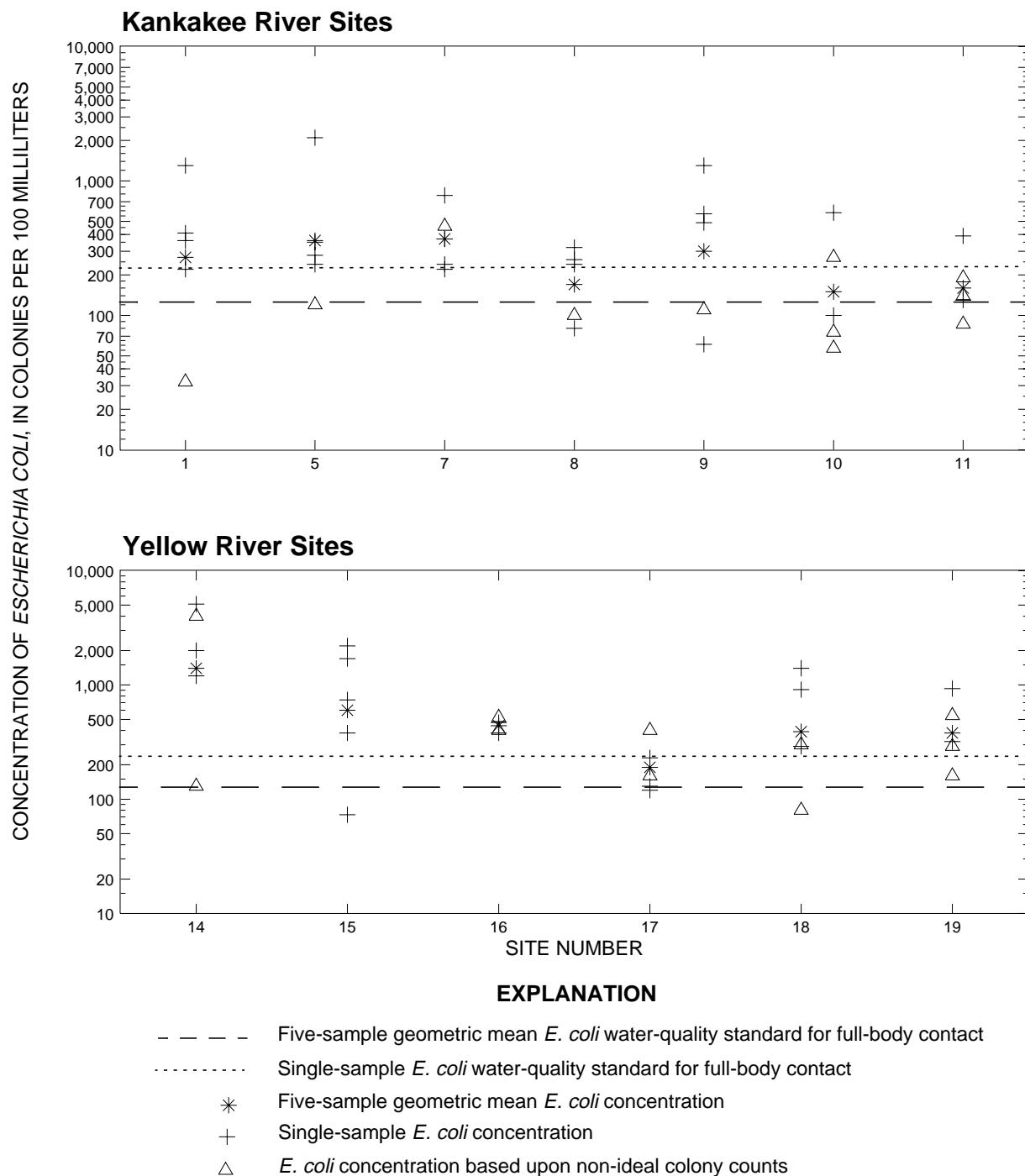
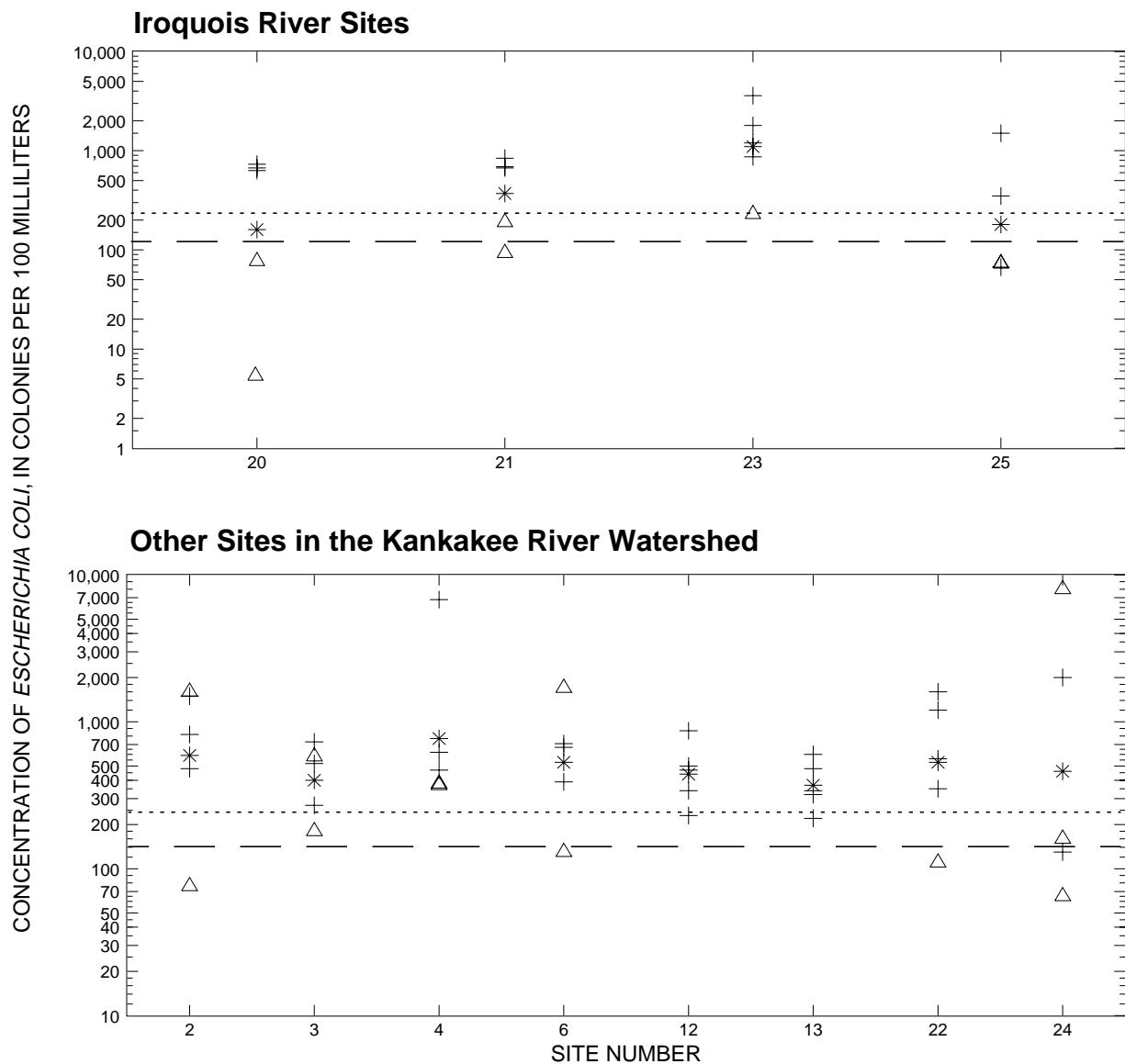


Figure 6. Concentrations of *Escherichia coli* and five-sample geometric means for Group 1 sites in the Kankakee River Watershed in Indiana, June–July 1999.



EXPLANATION

- - - - - Five-sample geometric mean *E. coli* water-quality standard for full-body contact
- Single-sample *E. coli* water-quality standard for full-body contact
- * Five-sample geometric mean *E. coli* concentration
- + Single-sample *E. coli* concentration
- △ *E. coli* concentration based upon non-ideal colony counts

Figure 6. Concentrations of *Escherichia coli* and five-sample geometric means for Group 1 sites in the Kankakee River Watershed in Indiana, June–July 1999—Continued.

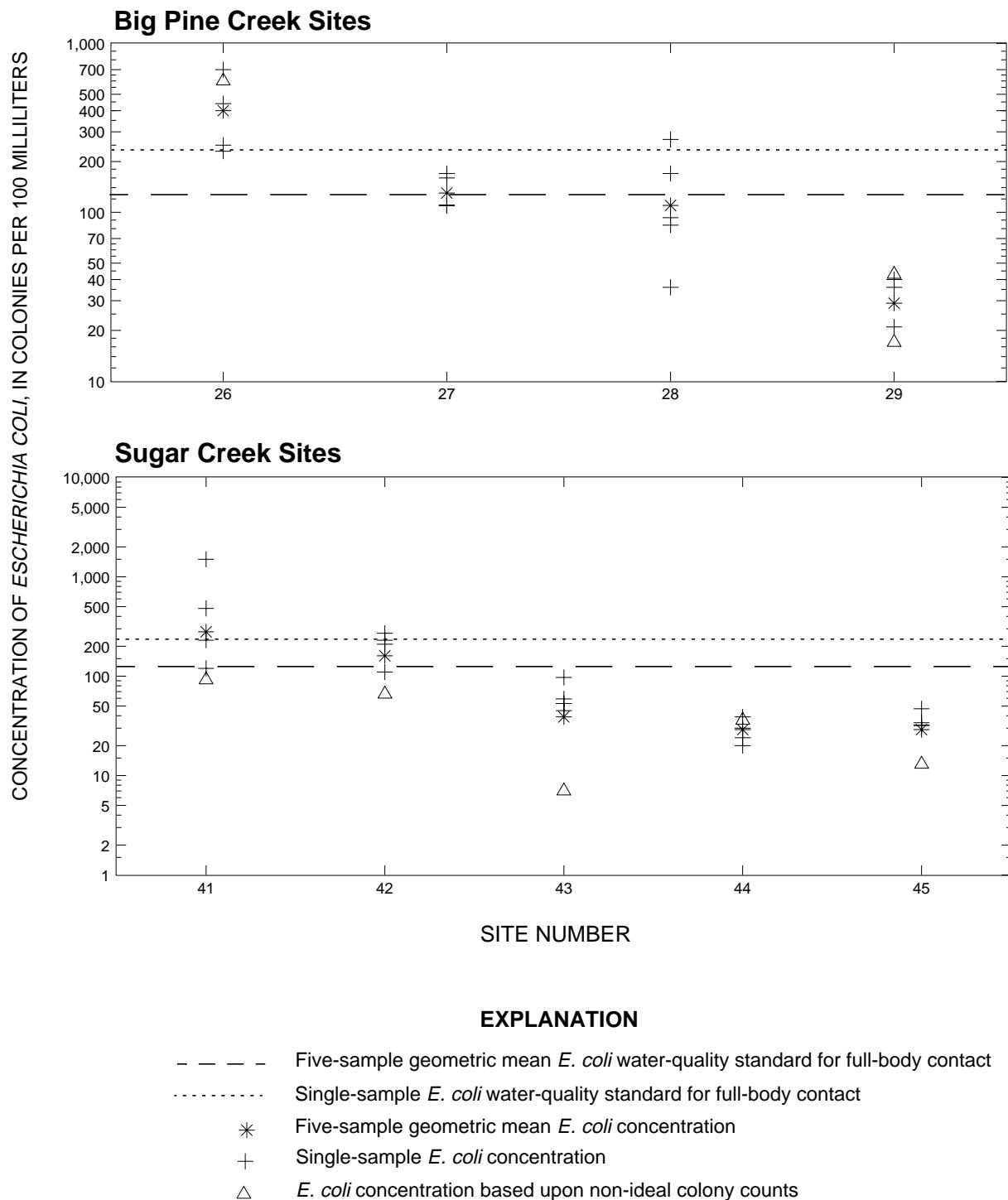


Figure 7. Concentration of *Escherichia coli* and five-sample geometric means for Group 1 and Group 2 sites in the Lower Wabash River Watershed in Indiana, June–September 1999.

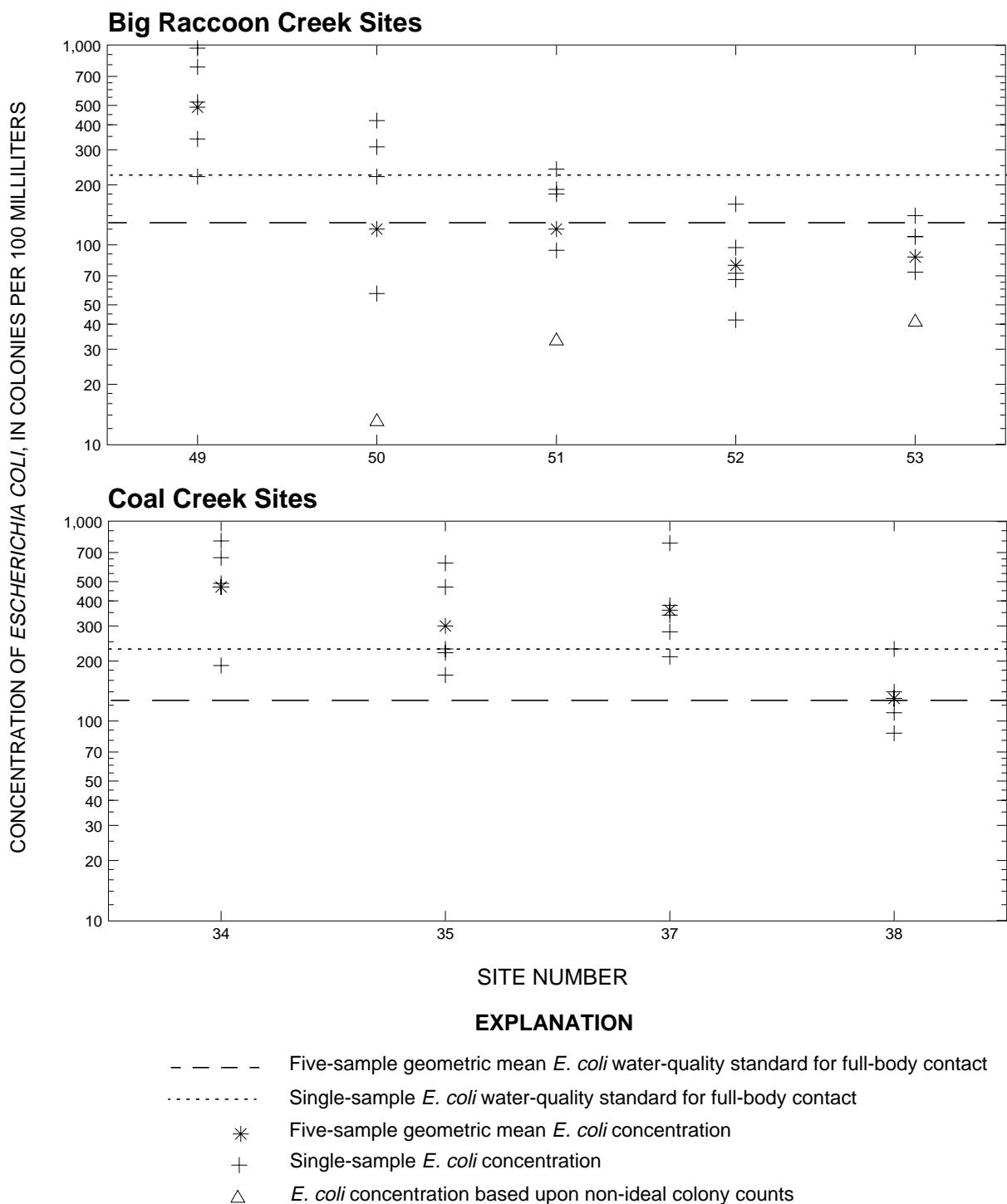


Figure 7. Concentration of *Escherichia coli* and five-sample geometric means for Group 1 and Group 2 sites in the Lower Wabash River Watershed in Indiana, June–September 1999—Continued.

CONCENTRATION OF *ESCHERICHIA COLI*, IN COLONIES PER 100 MILLILITERS

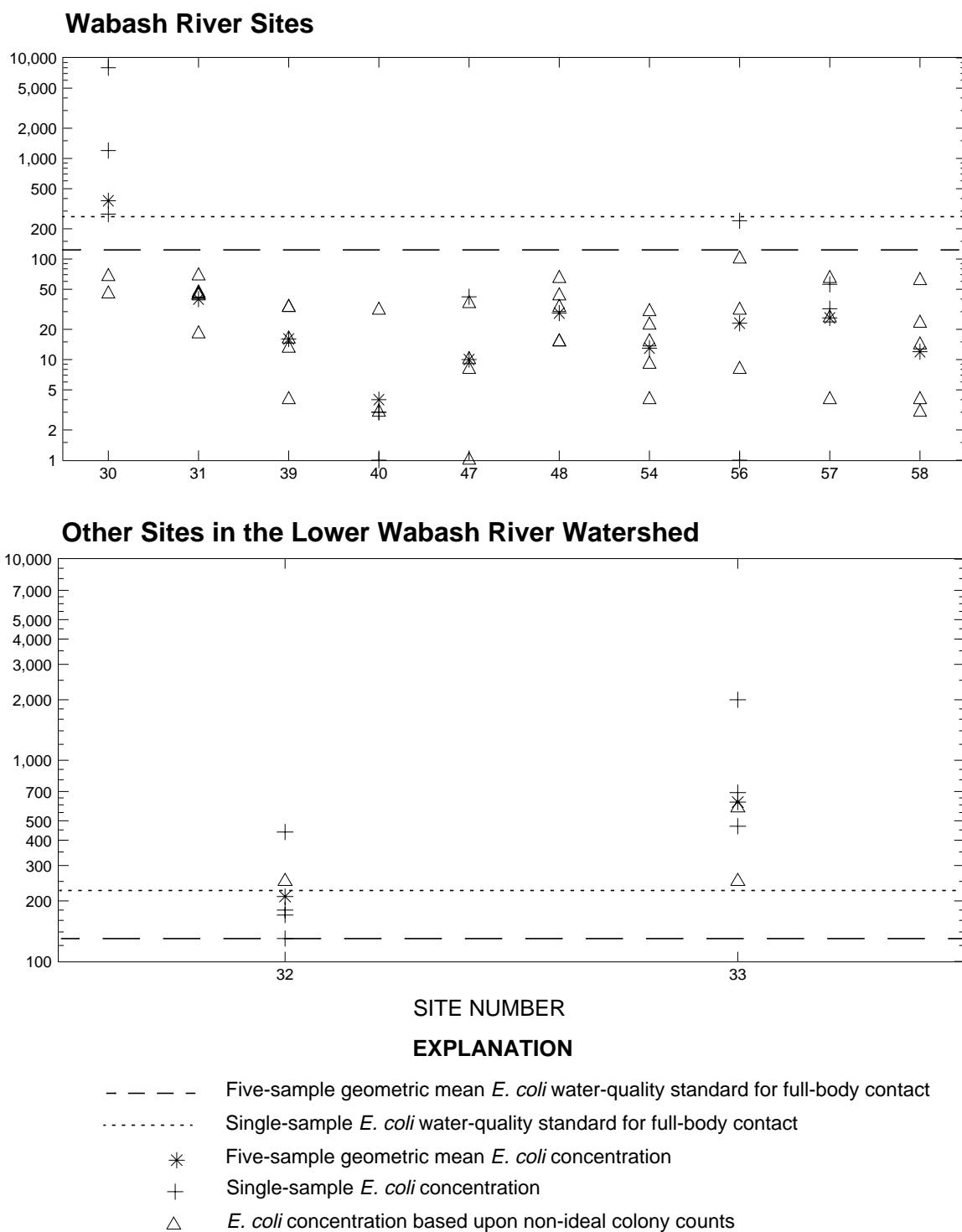


Figure 7. Concentration of *Escherichia coli* and five-sample geometric means for Group 1 and Group 2 sites in the Lower Wabash River Watershed in Indiana, June–September 1999—Continued.

Seven of 15 samples from three sites (49–51) on Big Raccoon Creek had concentrations of *E. coli* that exceeded the single-sample standard, and site 49 exceeded the standard for the five-sample geometric mean. Concentrations of *E. coli* in samples from Big Raccoon Creek ranged from 13 to 970 colonies per 100 mL. The five-sample geometric means ranged from 79 to 490 colonies per 100 mL. All 10 samples from two sites on Big Raccoon Creek (52 and 53) had concentrations that did not exceed the single-sample standard or the five-sample geometric-mean standard.

Ten of 15 samples from three sites (34, 35, and 37) on Coal Creek had concentrations that exceeded the single-sample standard. All of these sites had concentrations that exceeded the five-sample geometric-mean standard. Concentrations of *E. coli* in samples from Coal Creek ranged from 87 to 800 colonies per 100 mL. The five-sample geometric means ranged from 130 to 470 colonies per 100 mL.

Concentrations for three samples from site 30 on the Wabash River exceeded the single-sample standard. The five-sample geometric mean for site 30 also exceeded the five-sample standard. Site 30 was the only site on the Wabash River to exceed either the single-sample or the five-sample geometric-mean standards. Concentrations of *E. coli* in samples from the Wabash River sites ranged from less than 1 to 8,000 colonies per 100 mL. The five-sample geometric means ranged from 4 to 380 colonies per 100 mL.

Two sites having only one sampling location on a particular stream are shown as “other sites in the Lower Wabash River Watershed” on figure 7. Seven of 10 samples from these two sites had concentrations of *E. coli* that exceeded the single-sample standard. One of the two sites had concentrations of *E. coli* that exceeded the five-sample geometric mean.

Relation between Concentrations of *Escherichia coli* and Streamflow

The relation of concentration of *E. coli* to stream discharge was examined for selected sites in the Kankakee and Lower Wabash River Watershed

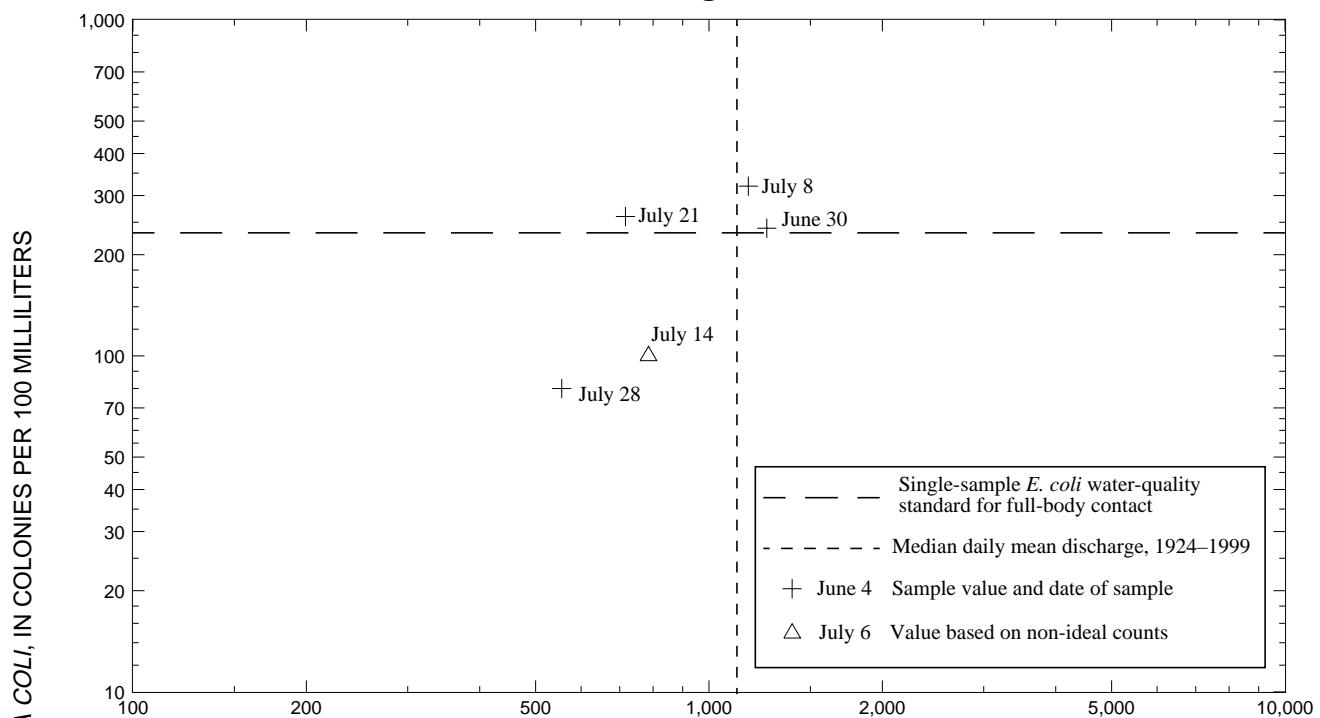
(figs. 8 and 9). Streamflow conditions varied during the 5-week sample-collection periods, June–July and August–September. This study was dependent more on collecting samples at the prescribed sample-collection times (five samples collected at evenly spaced intervals within a 30-day period) rather than at particular streamflow conditions. Stream discharges presented in this report were taken from data collected at USGS streamflow-gaging stations where stage-discharge relations have been developed. Ten of the 58 sites were at or near streamflow-gaging stations. Based on records of streamflow from these stations (Stewart and others, 2000), 18 percent of the samples collected at these sites were collected at discharges above the long-term daily mean discharge. Six of the Group 1 sites were at or near streamflow-gaging stations and 30 percent of the samples were collected at discharges above the long-term median daily mean discharge. Four of the Group 2 sites were at or near streamflow-gaging stations and none of the samples were collected at discharges above the long-term median daily mean discharge reported by Stewart and others (2000).

Analysis of figures 8 and 9 indicates that although concentrations of *E. coli* can exceed the single-sample standard during low stream discharge, the standard is always exceeded at discharges greater than the median daily mean.

Relation between Concentrations of *Escherichia coli* and Turbidity

To determine if there was a relation between concentrations of *E. coli* and turbidity, data for *E. coli* and turbidity from samples collected from 1998 (Silcox and others, 2000) and the study in 1999 were combined to provide a larger statistical base. Sixty-two percent of the samples were collected at discharges above the long-term median daily mean discharge during 1998, compared to 18 percent during 1999.

Site 8: Kankakee River at Dunns Bridge



Site 10: Kankakee River at Shelby

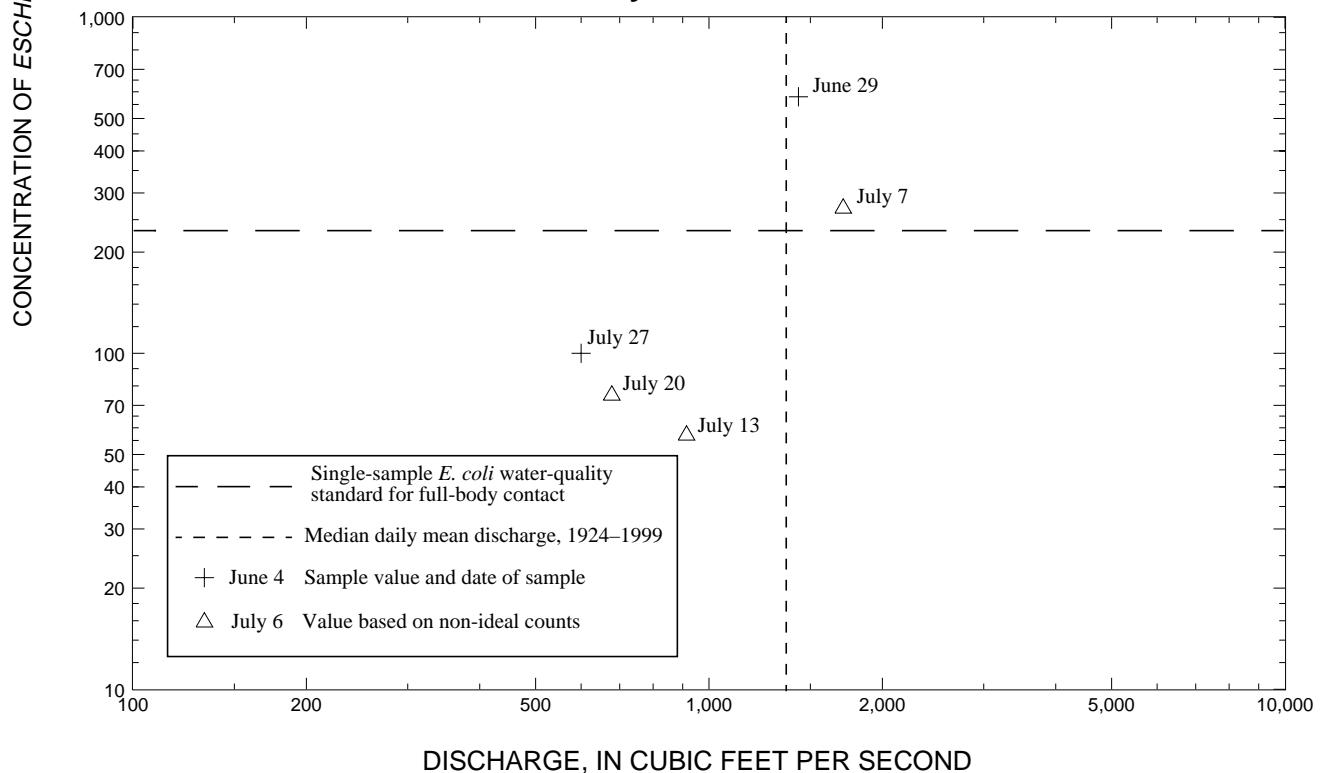
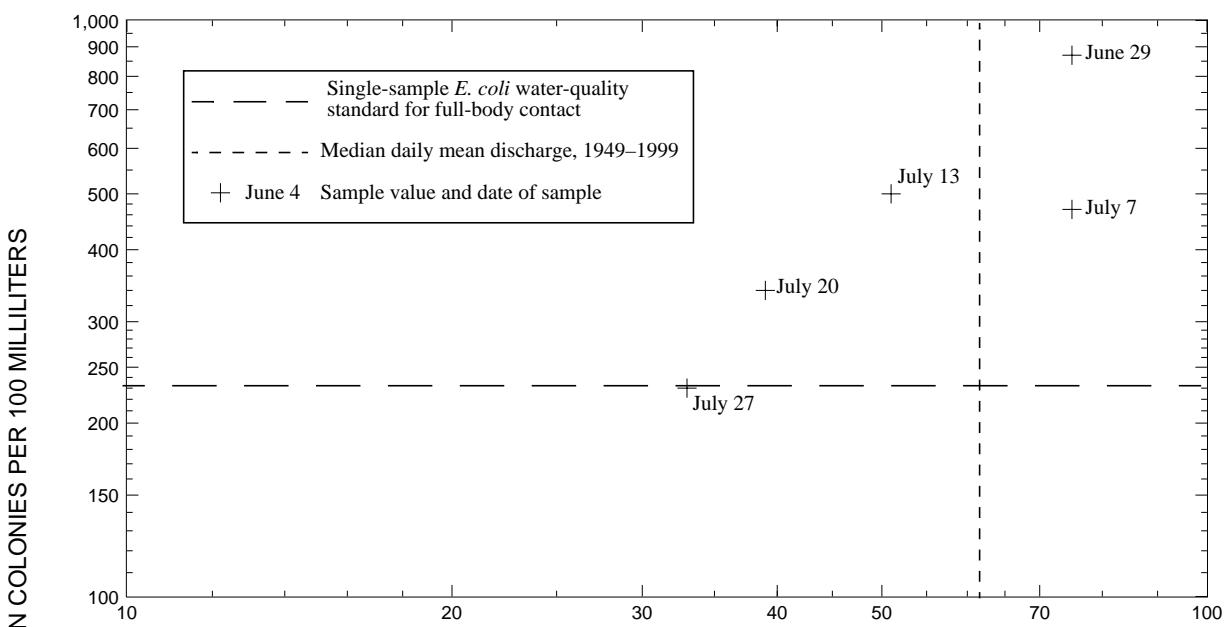


Figure 8. Stream discharge and concentrations of *Escherichia coli* at selected Group 1 sites in the Kankakee River Watershed in Indiana, June–July 1999.

Site 12: Singleton Ditch at Schneider



Site 18: Yellow River at Knox

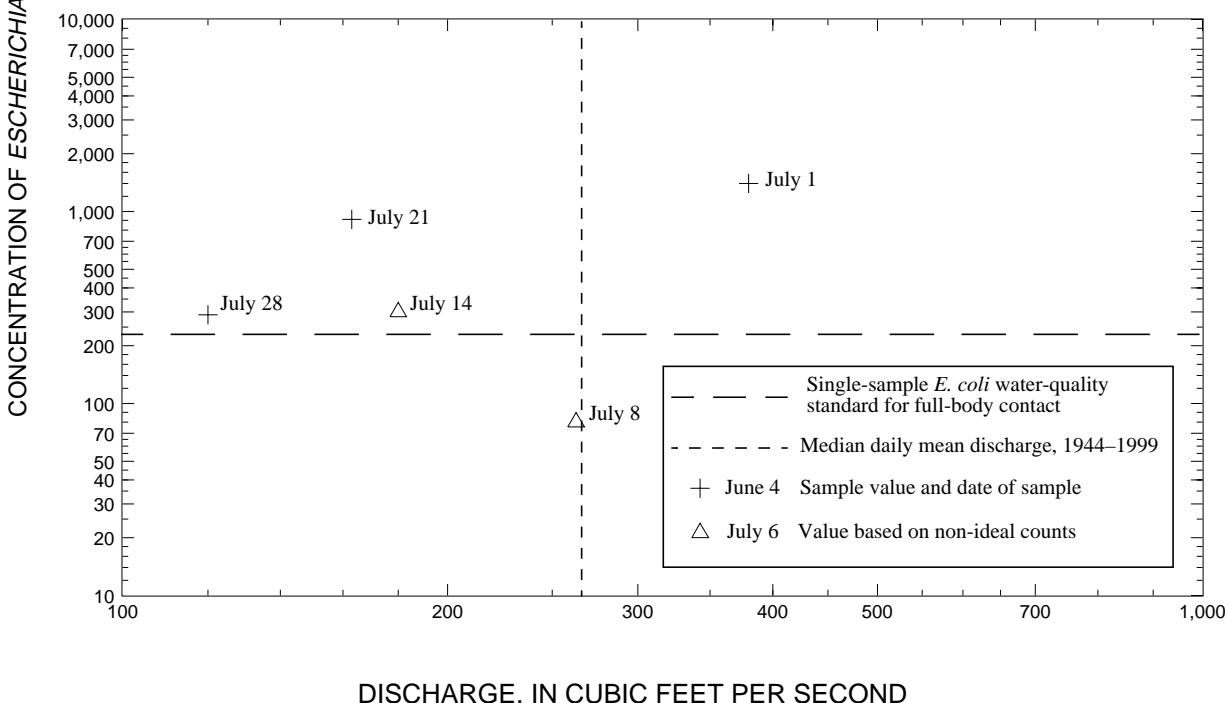
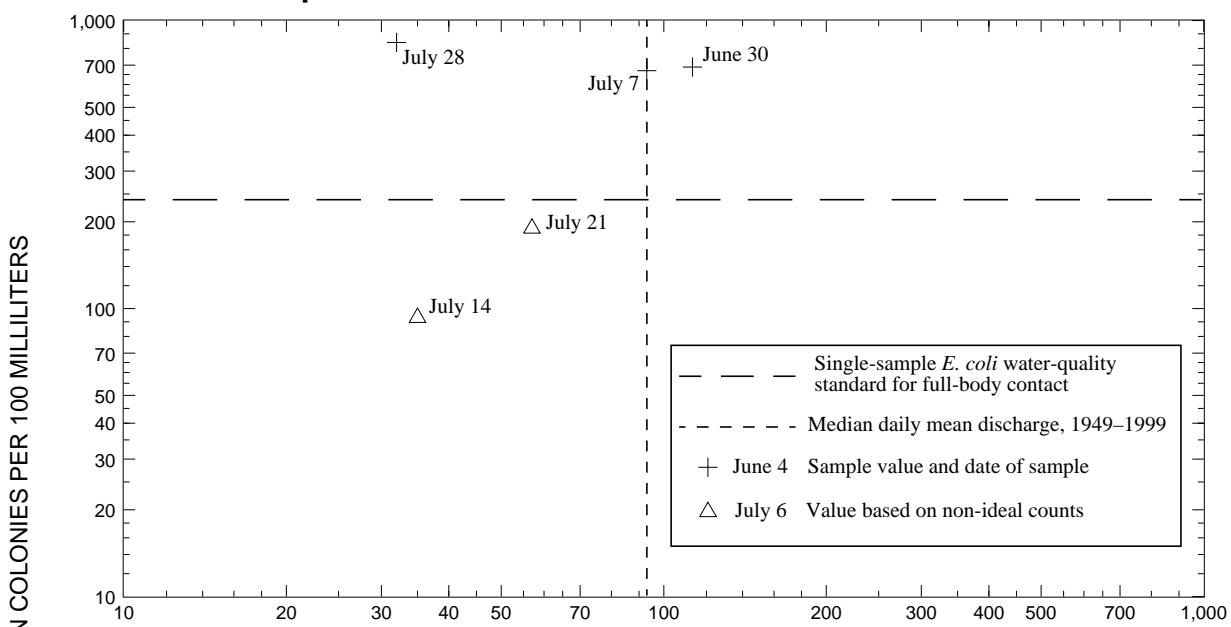


Figure 8. Stream discharge and concentrations of *Escherichia coli* at selected Group 1 sites in the Kankakee River Watershed in Indiana, June–July 1999—Continued.

Site 21: Iroquois River at Rensselaer



Site 23: Iroquois River near Foresman

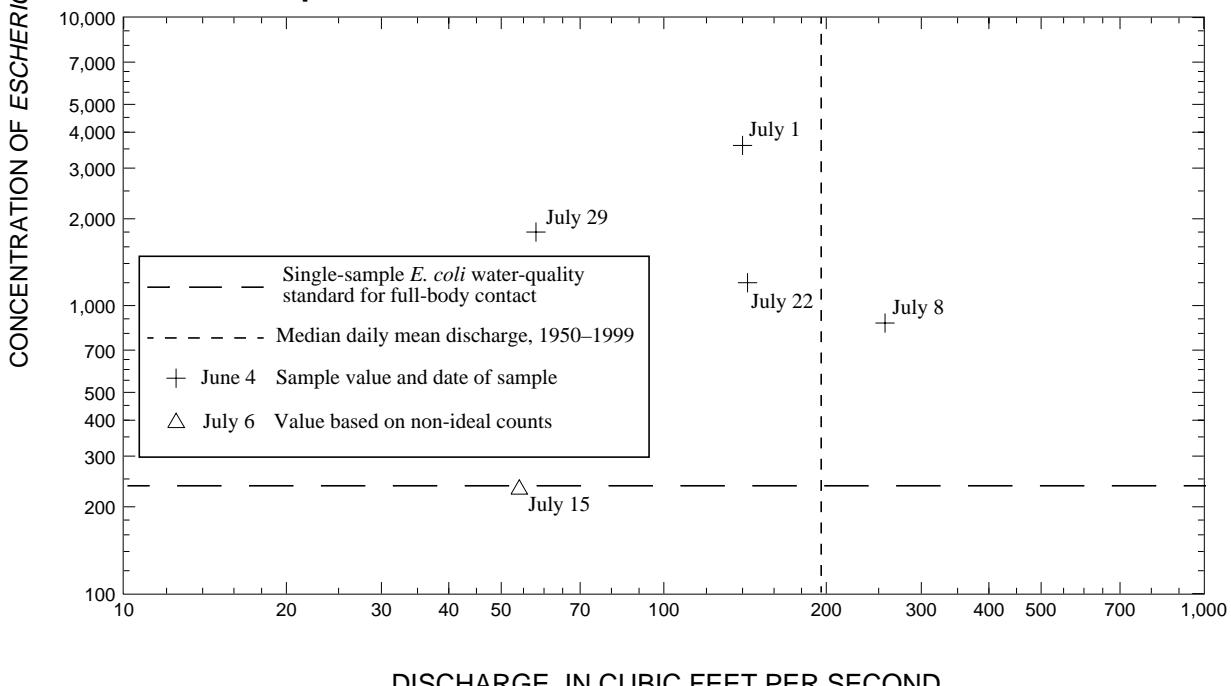
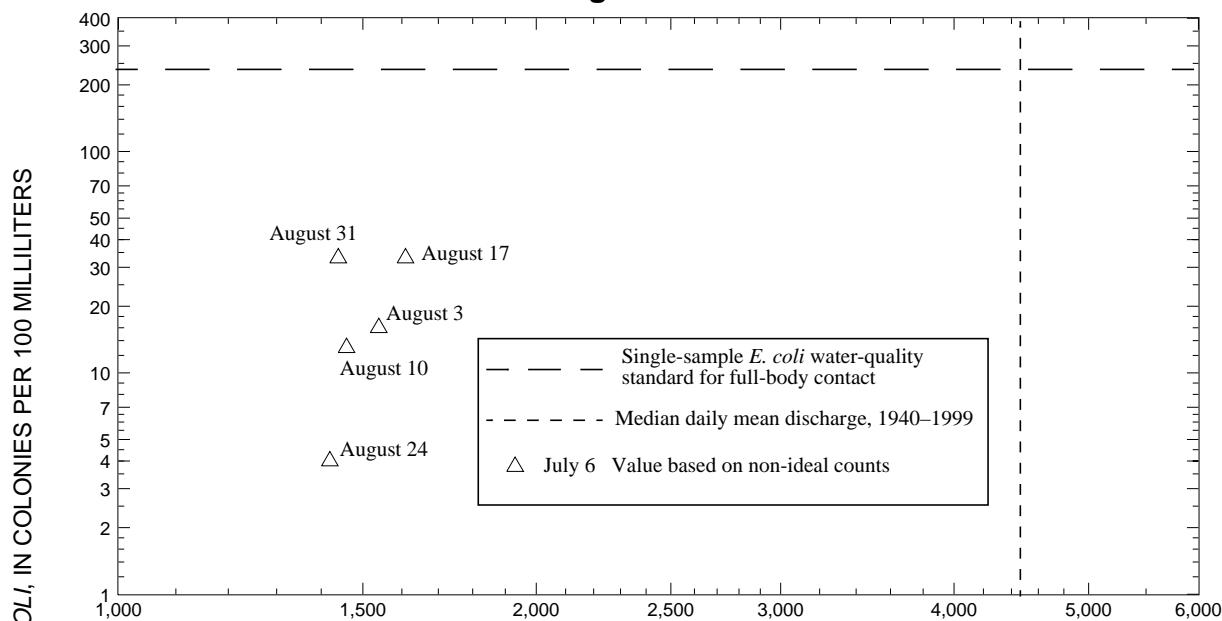


Figure 8. Stream discharge and concentrations of *Escherichia coli* at selected Group 1 sites in the Kankakee River Watershed in Indiana, June–July 1999—Continued.

Site 39: Wabash River at Covington



Site 47: Wabash River at Montezuma

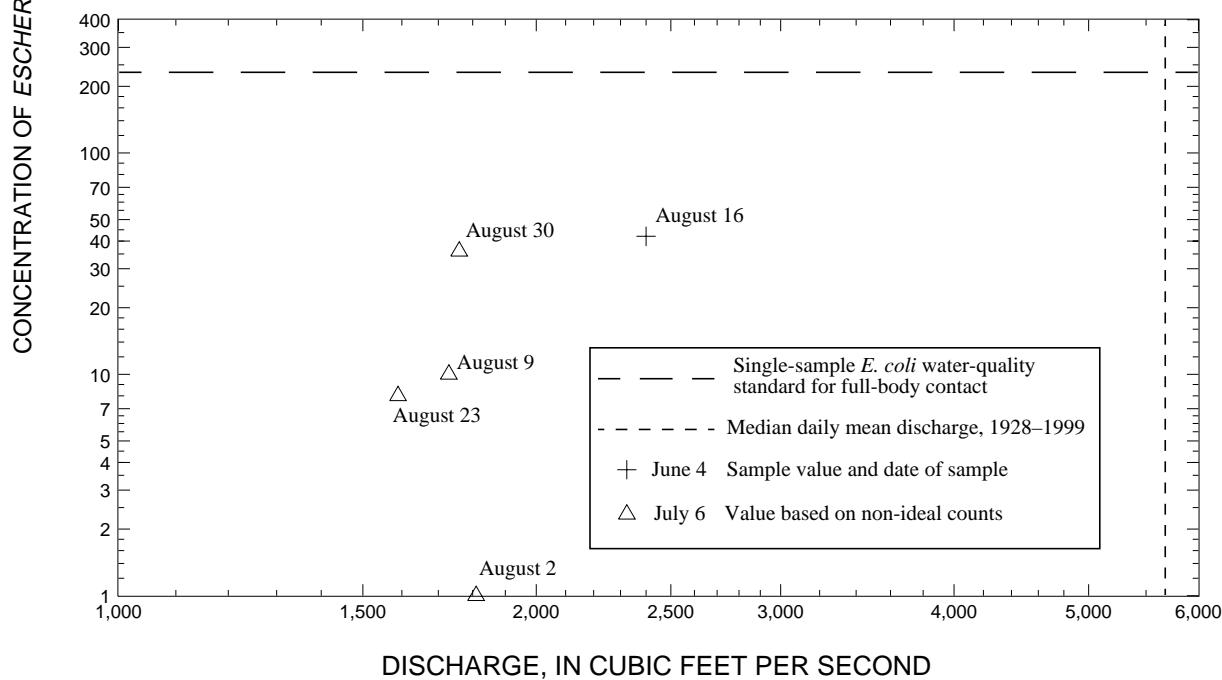
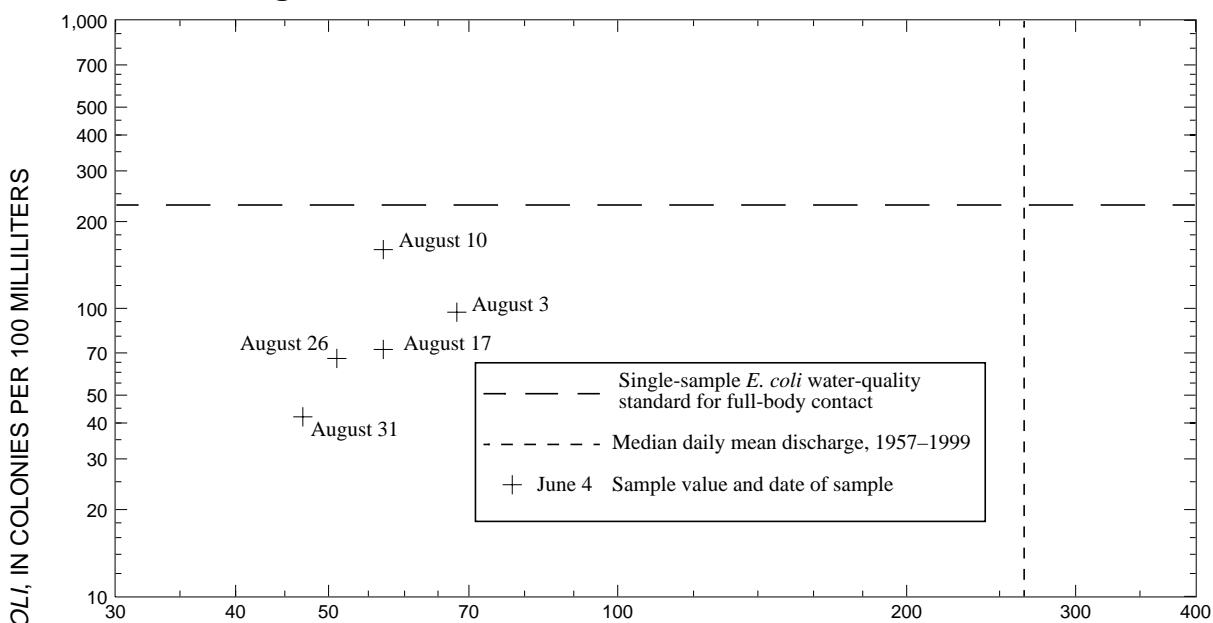


Figure 9. Stream discharge and concentrations of *Escherichia coli* at selected Group 2 sites in the Lower Wabash River Watershed in Indiana, August–September 1999.

Site 52: Big Raccoon Creek at Coxsburg



Site 56: Wabash River at Terre Haute

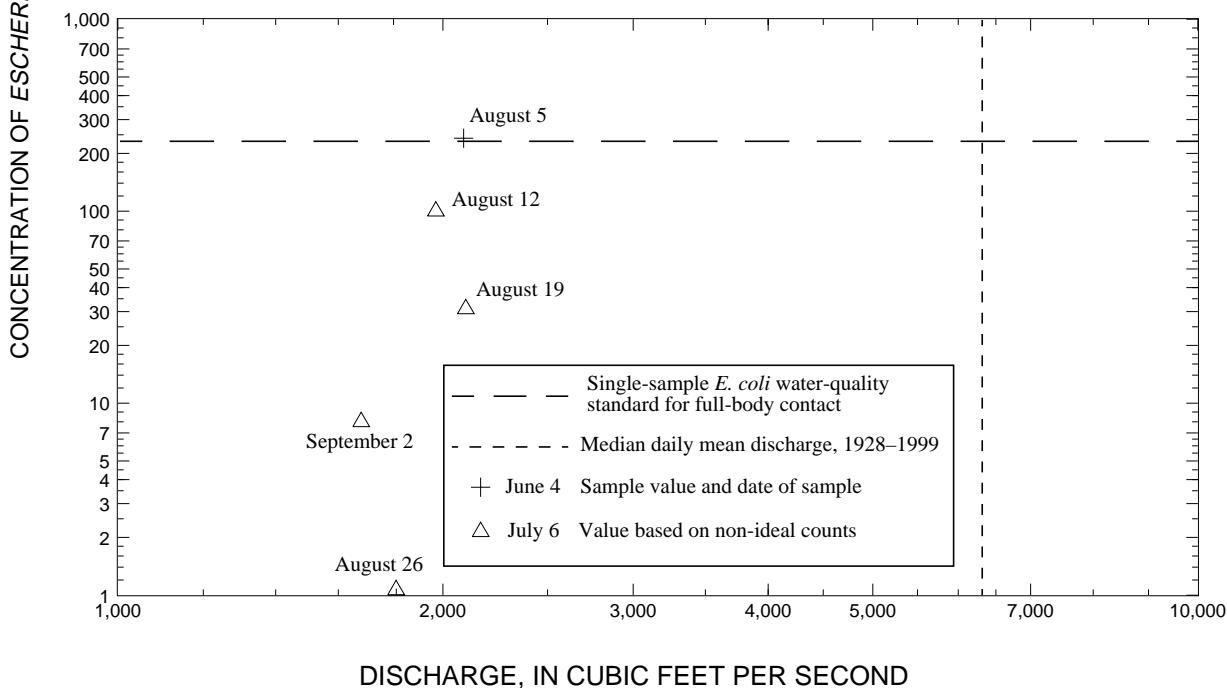


Figure 9. Stream discharge and concentrations of *Escherichia coli* at selected Group 2 sites in the Lower Wabash River Watershed in Indiana, August–September 1999—Continued.

Figure 10 displays scatter plots of concentration of *E. coli* versus turbidity for 1998, 1999, and for 1998 and 1999 combined. Turbidity and *E. coli* data were examined for the 2-year period because they were collected in the same way in both years. Data collected at these sites represented watersheds with different land uses and runoff rates and were sampled at different times.

A locally weighted scatterplot smoothing technique (LOWESS) was used to generate the line in the plot for the 1998 and 1999 combined data. The LOWESS method depicts the relation between turbidity and *E. coli* and accommodates outlying data (Helsel and Hirsch, 1992, p. 48). A statistically significant correlation ($p < 0.001$) was determined between concentrations of *E. coli* and turbidity for the 2-year data composite. If the turbidity measured during sample collection was greater than 83 NTU (nephelometric turbidity units), the sample always had concentrations of *E. coli* above the single-sample standard, indicating that runoff is a major factor affecting *E. coli* concentrations. If, however, the measured turbidity was less than 83 NTU, the concentrations of *E. coli* were not always below the single-sample standard, indicating other environmental or anthropogenic factors besides turbidity are influencing the concentrations of *E. coli*.

Summary

Water samples collected from 58 stream sites in the Kankakee and Lower Wabash River Watersheds from June through September 1999 were analyzed for concentrations of *E. coli*. Samples were collected at 29 sites during June and July, and at 29 different sites during August and September. A five-sample geometric mean was computed for each site. The five-sample geometric-mean concentrations ranged from 4 to 1,400 colonies per 100 mL, and concentrations for 38 sites exceeded the five-sample geometric-mean standard of 125 colonies per 100 mL. Of the 289 individual samples processed, 126 exceeded the single-sample standard of 235 colonies per 100 mL. Concentrations of *E. coli* ranged from less than 1 to greater than 8,000 colonies per 100 mL during the study.

Ten of the 58 sites were at or near USGS streamflow-gaging stations. Based on records from these stations, 18 percent of the samples collected at these sites were collected at streamflows above the median daily mean discharge.

E. coli concentration data and turbidity measurements collected in 1998 and 1999 showed a statistically significant correlation. The concentration of *E. coli* always exceeded the single-sample standard when the turbidity exceeded 83 NTU; however, when the measured turbidity was less than 83 NTU, concentrations of *E. coli* were not always below the single-sample standard.

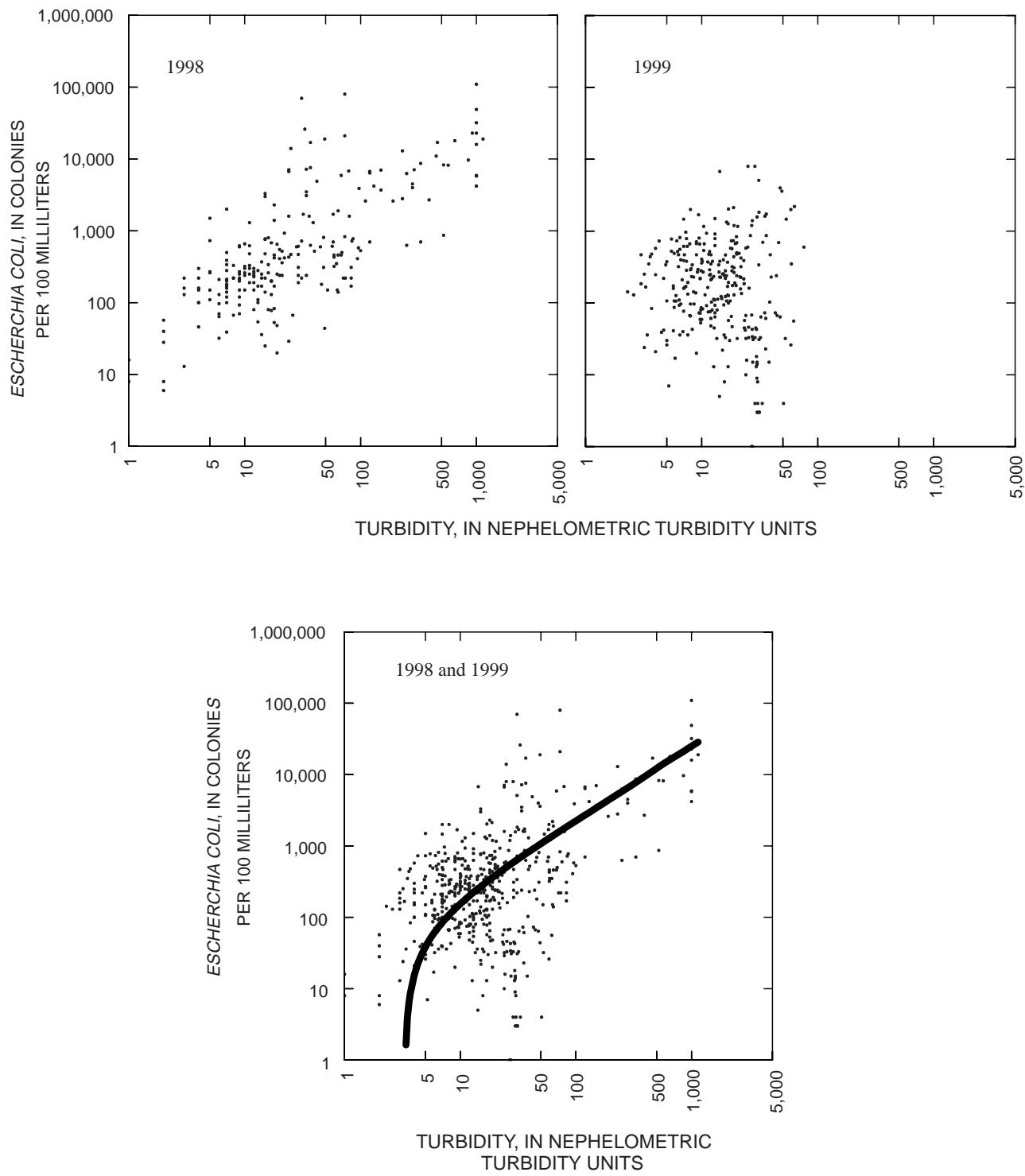


Figure 10. Turbidity and concentrations of *Escherichia coli* measured in samples collected at sites in the Kankakee and the Upper and Lower Wabash River Watersheds in Indiana, June–September 1998 (wet year) and 1999 (dry year).

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Supplemental Data

(Tables 3 and 4)

Table 3. Water-quality data for sampling sites in the Kankakee and Lower Wabash River Watersheds, June–September 1999
 [Time is in military notation; --, no data; K, values estimated from non-ideal colony counts; <, less than; >, greater than]

Site Number	Date	Time	Gage height (feet)	Discharge at time of sample collection (cubic feet per second)		Water temperature (degrees Celsius)	pH (Standard units)	Dissolved oxygen (milligrams per liter)	Specific conductance (microsiemens per centimeter)		<i>Escherichia coli</i> (colonies per 100 milliliters)
				at 25 degrees Celsius	at 25 degrees Celsius				at 25 degrees Celsius	at 25 degrees Celsius	
1	06-29-99	0850	87.58	--	18.0	7.8	7.1	704	16	1,300	
	07-07-99	1055	87.53	--	17.0	7.7	7.8	735	14	K32	
	07-13-99	0920	87.08	--	16.0	7.8	8.0	732	10	360	
	07-20-99	0900	87.00	--	18.5	7.7	7.1	727	10	410	
	07-27-99	1105	86.99	--	18.5	7.8	7.2	728	10	220	
	Five-sample geometric mean										270^a
2	06-29-99	0910	87.22	--	20.0	7.9	7.1	455	35	K1,600	
	07-07-99	1135	86.95	--	19.5	7.9	8.1	559	12	K76	
	07-13-99	0941	86.83	--	16.0	8.0	9.1	581	7	1,500	
	07-20-99	0920	86.80	--	19.5	7.9	7.7	567	6	820	
	07-27-99	1140	86.77	--	20.5	8.0	8.4	573	4	480	
	Five-sample geometric mean										590^a
3	06-29-99	0925	86.70	--	19.0	8.0	7.2	540	20	K180	
	07-07-99	1215	86.48	--	22.0	8.0	8.7	572	18	K580	
	07-13-99	1000	86.08	--	17.0	8.0	9.1	579	12	520	
	07-20-99	0940	86.05	--	21.0	7.9	6.7	572	18	730	
	07-27-99	1205	85.86	--	24.0	8.0	7.8	575	10	270	
	Five-sample geometric mean										400^a
4	06-29-99	0830	88.39	--	17.0	8.0	8.0	545	14	6,800	
	07-07-99	1010	88.44	--	17.0	7.9	8.6	569	11	K370	
	07-13-99	0852	88.22	--	15.0	7.9	9.0	570	7	620	
	07-20-99	0835	88.12	--	18.0	7.9	8.1	566	5	K380	
	07-27-99	1015	88.08	--	18.0	7.9	8.1	565	9	470	
	Five-sample geometric mean										770^a

Table 3. Water-quality data for sampling sites in the Kankakee and Lower Wabash River Watersheds, June–September 1999—Continued

Site Number	Date	Time	Gage height (feet)	Discharge at time of sample collection (cubic feet per second)	Water temperature (degrees Celsius)	pH (Standard units)	Dissolved oxygen (milligrams per liter)	Specific conductance (microsiemens per centimeter) at 25 degrees Celsius	Turbidity (Nephelometric turbidity units)	Escherichia coli (colonies per 100 milliliters)
5	06-29-99	0800	82.99	--	21.0	7.8	6.9	620	19	2,100
	07-07-99	0925	82.69	--	20.5	7.9	7.1	653	15	K120
	07-13-99	0822	82.00	--	19.0	7.9	8.0	659	16	280
	07-20-99	0810	81.76	--	21.5	7.9	7.4	651	12	350
	07-27-99	0930	81.55	--	21.0	7.9	6.8	652	12	240
	Five-sample geometric mean									
6	06-29-99	0730	85.10	--	17.5	7.7	6.5	666	9	K1,700
	07-07-99	0845	85.08	--	16.0	7.8	7.2	642	8	K130
	07-13-99	0800	84.80	--	15.0	7.8	7.7	676	7	390
	07-20-99	0745	84.88	--	17.0	7.7	6.8	696	9	670
	07-27-99	0900	84.73	--	17.0	7.7	6.3	696	9	710
	Five-sample geometric mean									
7	07-01-99	1335	88.12	--	20.0	7.7	7.2	570	17	370
	07-08-99	0915	87.28	--	20.5	7.7	6.9	629	16	K460
	07-14-99	0825	86.33	--	19.5	7.8	7.2	635	16	240
	07-21-99	0755	86.04	--	22.0	7.7	6.8	632	13	780
	07-28-99	0920	85.72	--	23.0	7.9	6.3	645	12	220
	Five-sample geometric mean									
8	06-30-99	0935	4.74	1,260	21.0	7.8	7.1	546	20	240
	07-08-99	0855	4.45	1,170	22.5	7.9	6.9	579	18	320
	07-14-99	0825	3.26	785	21.0	7.9	7.3	577	17	K100
	07-21-99	0805	3.02	716	24.0	7.9	7.1	601	15	260
	07-28-99	0826	2.45	555	24.5	7.9	6.6	609	14	80
	Five-sample geometric mean									

Table 3. Water-quality data for sampling sites in the Kankakee and Lower Wabash River Watersheds, June–September 1999—Continued

Table 3. Water-quality data for sampling sites in the Kankakee and Lower Wabash River Watersheds, June–September 1999—Continued

Site Number	Date	Time	Gage height (feet)	Discharge at time of sample collection (cubic feet per second)	Water temperature (degrees Celsius)	pH (Standard units)	Dissolved oxygen (milligrams per liter)	Specific conductance (microsiemens per centimeter) at 25 degrees Celsius	Turbidity (Nephelometric turbidity units)	Escherichia coli (colonies per 100 milliliters)
13	06-29-99	1125	85.61	--	21.5	7.9	8.5	766	20	480
	07-07-99	1040	85.50	--	21.5	7.8	8.1	841	31	340
	07-13-99	1015	85.44	--	20.0	7.9	10.5	851	16	220
	07-20-99	0945	85.43	--	22.5	7.8	7.9	921	22	320
	07-27-99	0941	85.20	--	23.0	7.9	9.2	930	76	600
Five-sample geometric mean										370
14	07-01-99	0725	81.90	--	19.0	7.8	6.9	576	47	K4,000
	07-09-99	0810	81.08	--	20.5	7.8	6.4	704	20	1,200
	07-15-99	0712	80.94	--	19.5	7.3	6.6	711	17	K130
	07-22-99	0705	80.84	--	24.0	7.8	5.7	732	17	2,000
	07-29-99	0935	80.84	--	22.5	7.5	3.7	483	31	5,100
Five-sample geometric mean										1,400^a
15	07-01-99	0800	76.88	--	21.0	7.9	7.0	563	36	1,700
	07-09-99	0850	76.46	--	22.0	7.9	6.3	657	19	740
	07-15-99	0750	76.18	--	21.0	7.9	6.8	653	14	380
	07-22-99	0740	76.06	--	24.5	7.9	6.2	668	13	73
	07-29-99	0820	76.91	--	22.5	7.6	5.5	419	63	2,200
Five-sample geometric mean										600
16	07-08-99	1235	81.04	--	21.5	7.9	7.5	727	12	380
	07-14-99	1030	--	--	18.5	7.9	8.4	755	7	K400
	07-21-99	0950	80.73	--	21.0	7.8	6.8	765	6	K520
	07-28-99	1155	80.70	--	22.5	8.0	7.4	803	6	470
	Five-sample geometric mean									

(geometric mean for site 16 computed by substituting a value of one colony per 100 milliliters for missing data, as explained on p. 10 of text)

Table 3. Water-quality data for sampling sites in the Kankakee and Lower Wabash River Watersheds, June–September 1999—Continued

Site Number	Date	Time	Gage height (feet)	Discharge at time of sample collection (cubic feet per second)	Water temperature (degrees Celsius)	pH (Standard units)	Dissolved oxygen (milligrams per liter)	Specific conductance (microsiemens per centimeter) at 25 degrees Celsius	Turbidity (Nephelometric turbidity units)	<i>Escherichia coli</i> (colonies per 100 milliliters)
17	06-28-99	1220	76.71	--	22.5	8.0	7.6	586	22	230
	07-06-99	1530	76.71	--	25.5	8.1	7.9	605	15	K400
	07-12-99	1305	76.10	--	21.5	8.2	9.8	697	11	K160
	07-19-99	1330	76.05	--	23.5	8.2	10.5	730	19	130
	07-26-99	1450	75.92	--	25.0	8.2	8.1	743	15	120
	Five-sample geometric mean									
18	07-01-99	1310	5.69	380	21.0	8.0	8.0	485	27	1,400
	07-08-99	1055	5.38	263	22.0	8.1	8.0	601	12	K80
	07-14-99	0930	5.15	180	20.0	8.1	8.3	616	8	K300
	07-21-99	0850	5.10	163	23.0	8.1	7.2	623	13	910
	07-28-99	1040	4.96	120	24.5	8.1	7.4	669	12	290
	Five-sample geometric mean									
19	07-01-99	1400	82.41	--	22.0	8.1	8.1	490	26	K160
	07-08-99	1005	81.97	--	23.0	8.2	8.2	588	10	K540
	07-14-99	0850	81.52	--	20.5	8.2	8.2	624	9	K290
	07-21-99	0818	81.52	--	23.5	8.2	7.5	614	11	930
	07-28-99	1000	81.33	--	25.5	8.2	7.6	658	6	320
	Five-sample geometric mean									
20	06-30-99	1140	84.71	--	21.0	7.9	9.1	529	13	630
	07-07-99	1215	84.61	--	23.5	7.9	9.1	545	10	670
	07-14-99	1015	84.37	--	20.5	8.0	9.4	512	7	K77
	07-21-99	1025	84.46	--	24.5	7.4	8.1	503	14	<5
	07-28-99	1016	83.34	--	25.5	7.9	6.2	524	4	730
	Five-sample geometric mean									

^a Geometric mean.

Table 3. Water-quality data for sampling sites in the Kankakee and Lower Wabash River Watersheds, June–September 1999—Continued

Site Number	Date	Time	Gage height (feet)	Discharge at time of sample collection (cubic feet per second)	Water temperature (degrees Celsius)	pH (Standard units)	Dissolved oxygen (milligrams per liter)	Specific conductance (microsiemens per centimeter)		<i>Escherichia coli</i> (colonies per 100 milliliters)
								at 25 degrees Celsius	at 25 degrees Celsius	
21	06-30-99	1210	4.54	113	21.5	7.8	7.4	550	20	690
	07-07-99	1245	4.45	93	24.5	7.8	7.4	570	20	670
	07-14-99	1050	3.62	35	21.0	7.9	7.7	562	13	K93
	07-21-99	1045	4.00	57	24.5	7.7	6.1	504	23	K190
	07-28-99	1045	3.56	32	26.0	7.9	4.4	566	20	840
	Five-sample geometric mean									
22	06-28-99	1530	81.84	--	23.0	7.7	7.0	440	30	1,600
	07-06-99	1325	80.32	--	25.0	8.0	7.2	633	6	560
	07-12-99	1300	79.90	--	21.0	8.0	9.1	580	4	350
	07-19-99	1230	80.58	--	24.5	7.9	7.2	630	6	K110
	07-26-99	1218	80.16	--	26.0	7.9	5.3	620	10	1,200
	Five-sample geometric mean									
23	07-08-99	1200	7.28	257	24.5	7.9	6.8	609	26	870
	07-01-99	0930	6.19	140	21.5	7.8	7.0	554	49	3,600
	07-15-99	0840	4.89	54	22.5	8.0	6.4	635	21	K230
	07-22-99	0810	6.23	143	25.5	7.7	5.6	449	27	1,200
	07-29-99	0821	4.98	58	27.0	7.8	4.6	644	31	1,800
	Five-sample geometric mean									
24	07-01-99	1020	83.42	--	23.0	8.1	7.3	612	58	2,000
	07-08-99	1230	83.89	--	29.5	8.6	15.2	727	17	130
	07-15-99	0920	82.83	--	23.5	7.9	4.8	711	18	K65
	07-22-99	0850	83.00	--	27.5	7.7	4.4	912	22	K160
	07-29-99	0856	83.02	--	28.0	7.9	3.5	871	29	>8,000
	Five-sample geometric mean									

Table 3. Water-quality data for sampling sites in the Kankakee and Lower Wabash River Watersheds, June–September 1999—Continued

Table 3. Water-quality data for sampling sites in the Kankakee and Lower Wabash River Watersheds, June–September 1999—Continued

Site Number	Date	Time	Gage height (feet)	Discharge at time of sample collection (cubic feet per second)		Water temperature (degrees Celsius)	pH (Standard units)	Dissolved oxygen (milligrams per liter)	Specific conductance (microsiemens per centimeter)		<i>Escherichia coli</i> (colonies per 100 milliliters)
				at time of sample collection	at time of sample collection				at 25 degrees Celsius	at 25 degrees Celsius	
29	08-03-99	1200	25.62	--	25.0	8.2	9.0	519	7	40	
	08-10-99	1040	25.16	--	22.5	8.1	8.3	528	6	36	
	08-17-99	1030	25.19	--	23.5	8.0	8.1	538	8	K43	
	08-24-99	1025	25.18	--	22.5	8.0	7.4	541	6	K17	
	08-31-99	1045	25.07	--	20.0	8.0	8.1	531	4	21	
	Five-sample geometric mean										29^a
30	06-28-99	1330	61.28	--	26.0	8.3	10.7	533	25	8,000	
	07-06-99	1215	61.10	--	28.5	8.4	12.1	537	18	280	
	07-12-99	1130	55.90	--	24.5	8.6	13.8	499	23	K45	
	07-19-99	1110	60.00	--	26.5	8.4	12.4	538	19	1,200	
	07-26-99	1105	60.07	--	29.5	8.3	12.4	542	24	K67	
	Five-sample geometric mean										380^a
31	08-05-99	0915	58.40	--	25.0	8.5	12.0	519	30	K43	
	08-12-99	0900	58.53	--	25.0	8.2	10.4	557	27	K68	
	08-19-99	0915	58.26	--	23.5	8.6	11.4	581	29	K45	
	08-26-99	0840	58.63	--	23.5	8.2	13.3	586	30	K18	
	09-02-99	0835	58.43	--	22.5	8.3	13.1	584	25	K46	
	Five-sample geometric mean										40^a
32	08-05-99	0955	68.91	--	20.0	8.2	9.5	578	3	170	
	08-12-99	0925	68.90	--	21.0	8.1	7.8	616	4	440	
	08-19-99	0935	68.91	--	19.0	8.2	9.7	622	3	180	
	08-26-99	0912	69.03	--	19.5	8.2	9.6	624	3	K250	
	09-02-99	0900	68.87	--	17.5	8.2	9.4	631	3	130	
	Five-sample geometric mean										210^a

Table 3. Water-quality data for sampling sites in the Kankakee and Lower Wabash River Watersheds, June–September 1999—Continued

Site Number	Date	Time	Gage height (feet)	Discharge at time of sample collection (cubic feet per second)	Water temperature (degrees Celsius)	pH (Standard units)	Dissolved oxygen (milligrams per liter)	Specific conductance (microsiemens per centimeter) at 25 degrees Celsius	Turbidity (Nephelometric turbidity units)	<i>Escherichia coli</i> (colonies per 100 milliliters)
33	06-28-99	1205	86.95	--	23.0	8.1	8.3	506	46	690
	07-06-99	1120	86.52	--	24.5	8.2	10.8	635	3	470
	07-12-99	1050	86.55	--	20.0	8.3	12.8	568	4	K250
	07-19-99	1030	86.63	--	23.0	8.2	10.1	564	8	2,000
	07-26-99	1010	86.52	--	24.0	8.1	9.7	647	4	K580
	Five-sample geometric mean									
34	08-05-99	1030	85.75	--	22.5	7.9	7.0	514	10	800
	08-12-99	0940	85.84	--	23.0	7.4	5.8	575	10	660
	08-19-99	1000	85.70	--	21.0	7.9	7.6	582	7	470
	08-26-99	0938	85.93	--	20.5	7.9	7.9	579	8	190
	09-02-99	0930	85.78	--	19.5	7.9	7.4	583	6	490
	Five-sample geometric mean									
35	08-02-99	1410	75.75	--	25.0	8.1	9.3	555	7	170
	08-09-99	1235	75.74	--	21.0	8.1	9.0	542	12	470
	08-16-99	1210	75.77	--	20.0	8.1	9.3	564	8	230
	08-23-99	1240	75.83	--	20.5	8.1	9.1	584	8	620
	08-30-99	1211	75.67	--	19.5	8.0	8.4	597	10	220
	Five-sample geometric mean									
36	08-02-99	1345	77.54	--	28.5	8.5	13.7	554	5	K26
	08-09-99	1210	77.57	--	24.0	8.5	12.6	530	7	160
	08-16-99	1155	77.57	--	23.5	8.4	12.1	567	10	83
	08-23-99	1221	77.63	--	23.0	8.4	11.9	569	2	140
	08-30-99	1145	77.51	--	22.0	8.3	11.2	589	9	97
	Five-sample geometric mean									
										86^a

Table 3. Water-quality data for sampling sites in the Kankakee and Lower Wabash River Watersheds, June–September 1999—Continued

Site Number	Date	Time	Gage height (feet)	Discharge at time of sample collection (cubic feet per second)	Water temperature (degrees Celsius)	pH (Standard units)	Dissolved oxygen (milligrams per liter)	Specific conductance (microsiemens per centimeter) at 25 degrees Celsius	Turbidity (Nephelometric turbidity units)	Escherichia coli (colonies per 100 milliliters)
37	08-04-99	1030	70.44	--	23.0	8.2	8.6	690	10	280
	08-11-99	0955	70.45	--	22.5	8.2	7.9	709	10	380
	08-18-99	1030	70.45	--	22.5	8.2	9.0	722	8	340
	08-25-99	1002	70.53	--	20.0	8.2	8.8	728	7	210
	09-01-99	1040	70.40	--	19.0	8.1	9.2	725	6	780
	Five-sample geometric mean									
38	08-04-99	0855	56.42	--	22.5	8.1	7.5	647	14	110
	08-11-99	0830	56.40	--	22.5	8.1	7.3	676	14	230
	08-18-99	0905	56.42	--	22.0	8.0	7.3	639	8	140
	08-25-99	1044	56.43	--	20.5	8.2	4.7	633	6	130
	09-01-99	0820	56.32	--	18.0	8.0	7.1	646	6	87
	Five-sample geometric mean									
39	08-03-99	1340	4.39	1,540	28.0	8.9	--	490	24	K16
	08-10-99	1135	4.28	1,460	24.5	8.7	15.2	542	30	K13
	08-17-99	1125	4.48	1,610	25.0	8.8	--	508	29	K33
	08-24-99	1140	4.23	1,420	24.5	8.6	13.6	542	33	K4
	08-31-99	1315	4.25	1,440	23.0	8.6	14.8	551	25	K33
	Five-sample geometric mean									
40	08-04-99	1145	57.02	--	27.5	8.7	14.5	491	27	<1
	08-11-99	1030	57.14	--	25.0	8.6	14.7	533	28	K31
	08-18-99	1100	57.34	--	25.5	8.7	15.5	508	31	<3
	08-25-99	0920	57.18	--	23.0	8.5	12.1	561	31	<3
	09-01-99	1155	56.99	--	23.0	8.6	14.7	552	30	K3
	Five-sample geometric mean									

Table 3. Water-quality data for sampling sites in the Kankakee and Lower Wabash River Watersheds, June–September 1999—Continued

Site Number	Date	Time	Gage height (feet)	Discharge at time of sample collection (cubic feet per second)	Water temperature (degrees Celsius)	pH (Standard units)	Dissolved oxygen (milligrams per liter)	Specific conductance (microsiemens per centimeter) at 25 degrees Celsius	Turbidity (Nephelometric turbidity units)	<i>Escherichia coli</i> (colonies per 100 milliliters)
41	06-28-99	1003	79.27	--	24.0	8.0	7.1	626	13	1,500
	07-06-99	1150	78.79	--	28.0	8.1	8.1	659	12	480
	07-12-99	1037	78.69	--	21.0	8.0	7.1	662	13	230
	07-19-99	1100	78.71	--	25.0	8.0	7.4	633	16	120
	07-26-99	1135	78.58	--	28.5	8.0	6.7	603	11	K92
Five-sample geometric mean										280^a
42	06-28-99	0915	75.73	--	24.0	8.1	6.8	629	14	270
	07-06-99	1055	72.87	--	27.0	8.0	7.0	667	8	K66
	07-12-99	0958	75.29	--	21.5	8.1	8.2	659	5	110
	07-19-99	1022	75.38	--	24.5	8.0	8.1	720	8	230
	07-26-99	1020	75.20	--	27.5	8.1	7.1	636	12	210
Five-sample geometric mean										160^a
43	08-02-99	1235	31.65	--	26.5	8.3	10.5	660	13	45
	08-09-99	1125	31.74	--	22.0	8.2	9.3	662	10	53
	08-16-99	1105	31.70	--	21.5	8.1	9.4	692	10	59
	08-23-99	1140	31.83	--	21.5	8.1	8.6	793	7	97
	08-30-99	1055	31.73	--	20.0	8.0	8.0	791	5	K7
Five-sample geometric mean										39^a
44	08-02-99	1055	69.99	--	25.0	8.3	9.1	611	9	20
	08-09-99	1015	69.98	--	22.0	8.4	9.6	730	5	30
	08-16-99	0950	70.00	--	21.0	8.2	10.6	653	3	24
	08-23-99	1115	66.87	--	22.5	8.4	11.7	728	4	39
	08-30-99	1102	69.86	--	21.0	8.3	13.2	721	3	K36
Five-sample geometric mean										29^a

Table 3. Water-quality data for sampling sites in the Kankakee and Lower Wabash River Watersheds, June–September 1999—Continued

Site Number	Date	Time	Gage height (feet)	Discharge at time of sample collection (cubic feet per second)	Water temperature (degrees Celsius)	pH (Standard units)	Dissolved oxygen (milligrams per liter)	Specific conductance (microsiemens per centimeter) at 25 degrees Celsius	Turbidity (Nephelometric turbidity units)	Escherichia coli (colonies per 100 milliliters)
45	08-02-99	1300	--	--	29.0	8.2	8.6	596	24	32
	08-09-99	1140	71.56	--	24.5	8.2	8.8	621	27	34
	08-16-99	1125	71.85	--	24.5	8.1	10.1	602	18	47
	08-23-99	1250	71.80	--	24.5	8.0	8.3	628	20	32
	08-30-99	1259	71.80	--	24.0	8.0	9.6	637	17	K13
	Five-sample geometric mean									
46	08-02-99	1200	76.81	--	26.0	8.1	8.4	502	13	64
	08-09-99	1055	76.79	--	22.0	8.0	8.4	526	12	48
	08-16-99	1040	76.79	--	21.0	8.0	9.6	488	10	80
	08-23-99	1200	76.77	--	22.5	8.0	8.3	615	12	250
	08-30-99	1208	76.76	--	21.5	7.9	8.1	504	10	59
	Five-sample geometric mean									
47	08-02-99	1415	3.40	1,810	30.5	8.8	10.6	524	27	K1
	08-09-99	1215	3.35	1,730	28.5	8.5	9.4	606	24	K10
	08-16-99	1300	3.78	2,400	28.0	8.7	13.3	527	24	42
	08-23-99	1340	3.26	1,590	29.0	8.2	6.9	573	16	K8
	08-30-99	1425	3.37	1,760	28.5	8.0	7.5	561	16	K36
	Five-sample geometric mean									
48	08-04-99	0930	53.71	--	26.0	8.4	10.8	525	28	K15
	08-11-99	0900	53.70	--	25.0	8.4	10.9	551	27	K43
	08-18-99	0915	53.91	--	25.0	8.4	12.2	508	32	K33
	08-25-99	1122	53.73	--	23.5	8.5	12.9	572	30	K15
	09-01-99	0905	53.56	--	22.0	8.3	9.5	576	32	K64
	Five-sample geometric mean									

Table 3. Water-quality data for sampling sites in the Kankakee and Lower Wabash River Watersheds, June–September 1999—Continued

Table 3. Water-quality data for sampling sites in the Kankakee and Lower Wabash River Watersheds, June–September 1999—Continued

Site Number	Date	Time	Gage height (feet)	Discharge at time of sample collection (cubic feet per second)	Water temperature (degrees Celsius)	pH (Standard units)	Dissolved oxygen (milligrams per liter)	Specific conductance (microsiemens per centimeter)		<i>Escherichia coli</i> (colonies per 100 milliliters)
								at 25 degrees Celsius	at 25 degrees Celsius	
53	08-03-99	1010	69.39	--	23.0	8.1	7.8	556	10	73
	08-10-99	0925	69.28	--	21.0	8.1	8.3	571	6	110
	08-17-99	1030	69.27	--	22.5	8.1	9.5	542	6	110
	08-24-99	1100	69.16	--	22.5	8.0	7.8	561	9	140
	08-31-99	1118	69.06	--	20.5	8.1	10.0	548	6	K41
	Five-sample geometric mean									
54	08-03-99	1120	72.80	--	27.5	8.2	7.9	538	38	K15
	08-10-99	1010	72.35	--	26.5	8.3	8.1	616	30	K9
	08-17-99	1130	69.02	--	27.0	8.5	10.9	530	29	K4
	08-24-99	1130	73.49	--	27.0	7.8	5.5	584	15	K22
	08-31-99	1245	73.46	--	25.5	7.8	6.8	572	17	K30
	Five-sample geometric mean									
55	08-05-99	0745	77.53	--	22.5	7.9	7.2	757	8	290
	08-12-99	0715	77.45	--	23.0	7.9	6.9	843	7	280
	08-19-99	0745	77.39	--	21.0	7.9	8.8	830	8	670
	08-26-99	0915	77.40	--	21.0	7.8	7.7	9	6	730
	09-02-99	0748	77.28	--	20.5	7.9	7.8	913	7	380
	Five-sample geometric mean									
56	08-05-99	0900	.76	2,090	29.0	8.1	8.6	548	44	240
	08-12-99	0800	.67	1,970	30.5	8.0	7.1	607	38	K100
	08-19-99	0900	.77	2,100	29.0	8.1	7.8	539	31	K31
	08-26-99	1000	.55	1,810	28.0	7.9	7.0	611	27	<1
	09-02-99	0840	.45	1,680	28.5	8.1	8.4	595	30	K8
	Five-sample geometric mean									

Table 3. Water-quality data for sampling sites in the Kankakee and Lower Wabash River Watersheds, June–September 1999—Continued

Site Number	Date	Time	Gage height (feet)	Discharge at time of sample collection (cubic feet per second)		Water temperature (degrees Celsius)	pH (Standard units)	Dissolved oxygen (milligrams per liter)	Specific conductance (microsiemens per centimeter)		<i>Escherichia coli</i> (colonies per 100 milliliters)
				at 25 degrees Celsius	Turbidity (Nephelometric turbidity units)						
57	08-04-99	1415	4.57	--	29.5	8.7	12.9	515	62	56	
	08-11-99	1120	4.43	--	27.5	8.3	11.1	549	52	32	
	08-18-99	1315	4.73	--	27.5	8.4	10.6	590	59	K26	
	08-25-99	1245	4.35	--	26.5	8.2	8.2	549	47	K64	
	09-01-99	1320	4.40	--	26.5	8.5	12.7	584	51	K4	
	Five-sample geometric mean										26^a
58	08-04-99	1115	46.41	--	29.0	8.1	8.5	566	30	K14	
	08-11-99	0915	46.26	--	27.5	8.0	8.4	587	30	K4	
	08-18-99	1040	46.00	--	27.0	8.1	9.4	596	36	K23	
	08-25-99	1020	--	--	26.5	8.1	8.1	636	36	K61	
	09-01-99	1043	45.88	--	25.0	8.1	7.7	625	30	K3	
	Five-sample geometric mean										12^a

^aFive-sample geometric mean was calculated by use of one or more samples having non-ideal colony counts.

Table 4. Quality-assurance data associated with *Escherichia coli* samples collected in the Kankakee and Lower Wabash River Watershed in Indiana, June–September 1999

[Time is in military notation; --, no data; K, non-ideal colony count; <, less than; >, greater than]

Site number	Date	Time	Concentration of <i>Escherichia coli</i>					Natural log percent difference between environmental and duplicate samples
			Environmental sample (colonies per 100 milliliters)	Filter blank (colonies per 100 milliliters)	Process blank (colonies per 100 milliliters)	Field blank (colonies per 100 milliliters)	Concurrent duplicate (colonies per 100 milliliters)	
1	06-29-99	0850	1,300	0	--	--	--	--
	07-07-99	1055	K32	0	--	--	--	--
	07-13-99	0920	360	0	--	--	--	--
	07-20-99	0900	410	0	--	--	--	--
	07-27-99	1105	220	0	--	--	--	--
2	06-29-99	0910	K1,600	0	--	--	--	--
	07-07-99	1135	K76	0	1	--	--	--
	07-13-99	0941	1,500	0	--	--	--	--
	07-20-99	0920	820	0	--	--	--	--
	07-27-99	1140	480	0	--	--	--	--
3	06-29-99	0925	K180	0	--	--	--	--
	07-07-99	1215	K580	0	--	--	--	--
	07-13-99	1000	520	0	--	--	--	--
	07-20-99	0940	730	0	--	--	--	--
	07-27-99	1205	270	0	--	--	--	--
4	06-29-99	0830	6,800	0	--	--	--	--
	07-07-99	1010	K370	0	--	--	K220	52
	07-13-99	0852	620	0	--	--	--	--
	07-20-99	0835	K380	0	0	--	--	--
	07-27-99	1015	470	0	--	--	--	--
5	06-29-99	0800	2,100	0	--	--	--	--
	07-07-99	0925	K120	0	--	0	--	--
	07-13-99	0822	280	0	--	--	--	--
	07-20-99	0810	350	0	--	--	--	--
	07-27-99	0930	240	0	--	0	220	9

Table 4. Quality-assurance data associated with *Escherichia coli* samples collected in the Kankakee and Lower Wabash River Watershed in Indiana, June–September 1999—Continued

Site number	Date	Time	Concentration of <i>Escherichia coli</i>					Natural log percent difference between environmental and duplicate samples
			Environmental sample (colonies per 100 milliliters)	Filter blank (colonies per 100 milliliters)	Process blank (colonies per 100 milliliters)	Field blank (colonies per 100 milliliters)	Concurrent duplicate (colonies per 100 milliliters)	
6	06-29-99	0730	K1,700	0	2	--	--	--
	07-07-99	0845	K130	0	--	--	--	--
	07-13-99	0800	390	0	0	--	--	--
	07-20-99	0745	670	0	--	--	--	--
	07-27-99	0900	710	0	--	--	--	--
7	07-01-99	1335	370	0	0	--	--	--
	07-08-99	0915	K460	0	--	--	K110	143
	07-14-99	0825	240	0	0	--	--	--
	07-21-99	0755	780	0	0	--	--	--
	07-28-99	0920	220	0	--	--	--	--
8	06-30-99	0935	240	0	0	0	720	-110
	07-08-99	0855	320	0	--	--	--	--
	07-14-99	0825	K100	0	--	--	--	--
	07-21-99	0805	260	0	0	--	--	--
	07-28-99	0826	80	0	--	--	--	--
9	06-30-99	1100	490	0	--	--	--	--
	07-08-99	0955	570	0	1	0	--	--
	07-14-99	0915	K110	0	--	--	--	--
	07-21-99	0930	1,300	0	--	--	--	--
	07-28-99	0917	K61	0	--	--	120	-68
10	06-29-99	1155	580	0	--	--	--	--
	07-07-99	1115	K270	0	--	--	--	--
	07-13-99	1040	K57	0	--	--	--	--
	07-20-99	1010	K75	0	--	--	--	--
	07-27-99	1016	100	0	--	--	110	-10

Table 4. Quality-assurance data associated with *Escherichia coli* samples collected in the Kankakee and Lower Wabash River Watershed in Indiana, June–September 1999—Continued

Site number	Date	Time	Concentration of <i>Escherichia coli</i>					Natural log percent difference between environmental and duplicate samples
			Environmental sample (colonies per 100 milliliters)	Filter blank (colonies per 100 milliliters)	Process blank (colonies per 100 milliliters)	Field blank (colonies per 100 milliliters)	Concurrent duplicate (colonies per 100 milliliters)	
11	06-29-99	0940	390	0	--	--	--	--
	07-07-99	0855	K190	0	--	--	--	--
	07-13-99	0845	K140	0	--	0	--	--
	07-20-99	0815	130	0	--	--	--	--
	07-27-99	0815	K86	0	--	--	--	--
12	06-29-99	1045	870	0	--	--	--	--
	07-07-99	0955	470	0	0	--	--	--
	07-13-99	0930	500	0	--	--	380	27
	07-20-99	0905	340	0	0	--	--	--
	07-27-99	0849	230	0	0	--	--	--
13	06-29-99	1125	480	0	0	--	--	--
	07-07-99	1040	340	0	--	--	--	--
	07-13-99	1015	220	0	--	--	--	--
	07-20-99	0945	320	0	--	--	--	--
	07-27-99	0941	600	0	--	--	--	--
14	07-01-99	0725	K4,000	0	7	--	--	--
	07-09-99	0810	1,200	0	0	--	--	--
	07-15-99	0712	K130	0	0	--	K110	17
	07-22-99	0705	2,000	0	--	--	--	--
	07-29-99	0935	5,100	0	4	--	--	--
15	07-01-99	0800	1,700	0	--	--	--	--
	07-09-99	0850	740	0	--	--	--	--
	07-15-99	0750	380	0	--	--	--	--
	07-22-99	0740	73	0	0	--	290	-138
	07-29-99	0820	2,200	0	--	--	--	--

Table 4. Quality-assurance data associated with *Escherichia coli* samples collected in the Kankakee and Lower Wabash River Watershed in Indiana, June–September 1999—Continued

Site number	Date	Time	Concentration of <i>Escherichia coli</i>					Natural log percent difference between environmental and duplicate samples
			Environmental sample (colonies per 100 milliliters)	Filter blank (colonies per 100 milliliters)	Process blank (colonies per 100 milliliters)	Field blank (colonies per 100 milliliters)	Concurrent duplicate (colonies per 100 milliliters)	
16	07-08-99	1235	380	0	2	--	--	--
	07-14-99	1030	K400	0	--	--	--	--
	07-21-99	0950	K520	0	--	--	--	--
	07-28-99	1155	470	0	0	--	--	--
17	06-28-99	1220	230	0	--	--	--	--
	07-06-99	1530	K400	0	0	--	--	--
	07-12-99	1305	K160	0	--	--	K110	37
	07-19-99	1330	130	0	0	--	--	--
	07-26-99	1450	120	0	0	--	--	--
18	07-01-99	1310	1,400	0	--	--	--	--
	07-08-99	1055	K80	0	--	--	--	--
	07-14-99	0930	K300	0	--	--	--	--
	07-21-99	0850	910	0	--	--	--	--
	07-28-99	1040	290	0	--	--	200	37
19	07-01-99	1400	K160	0	--	--	--	--
	07-08-99	1005	K540	0	--	--	--	--
	07-14-99	0850	K290	0	--	--	--	--
	07-21-99	0818	930	0	--	--	1,100	-17
	07-28-99	1000	320	0	--	--	--	--
20	06-30-99	1140	630	0	0	--	--	--
	07-07-99	1215	670	0	--	--	--	--
	07-14-99	1015	K77	0	--	--	--	--
	07-21-99	1025	<5	0	--	--	--	--
	07-28-99	1016	730	0	0	--	--	--

Table 4. Quality-assurance data associated with *Escherichia coli* samples collected in the Kankakee and Lower Wabash River Watershed in Indiana, June–September 1999—Continued

Site number	Date	Time	Concentration of <i>Escherichia coli</i>					Natural log percent difference between environmental and duplicate samples
			Environmental sample (colonies per 100 milliliters)	Filter blank (colonies per 100 milliliters)	Process blank (colonies per 100 milliliters)	Field blank (colonies per 100 milliliters)	Concurrent duplicate (colonies per 100 milliliters)	
21	06-30-99	1210	690	0	--	--	--	--
	07-07-99	1245	670	0	--	--	--	--
	07-14-99	1050	K93	0	--	--	K52	58
	07-21-99	1045	K190	0	--	--	--	--
	07-28-99	1045	840	0	--	--	--	--
22	06-28-99	1530	1,600	0	--	--	K330	158
	07-06-99	1325	560	0	--	--	--	--
	07-12-99	1300	350	0	--	--	--	--
	07-19-99	1230	K110	0	--	--	--	--
	07-26-99	1218	1,200	0	--	--	--	--
23	07-08-99	1200	870	0	--	--	--	--
	07-01-99	0930	3,600	0	--	--	--	--
	07-15-99	0840	K230	0	--	--	--	--
	07-22-99	0810	1,200	0	4	--	--	--
	07-29-99	0821	1,800	0	0	--	--	--
24	07-01-99	1020	2,000	0	3	--	--	--
	07-08-99	1230	130	0	--	--	120	8
	07-15-99	0920	K65	0	--	--	--	--
	07-22-99	0850	K160	0	--	--	--	--
	07-29-99	0856	>8,000	0	--	--	--	--
25	07-01-99	0855	1,500	0	--	--	--	--
	07-08-99	1115	67	0	--	--	--	--
	07-15-99	0805	K73	0	--	--	--	--
	07-22-99	0740	K73	0	--	0	K76	-4
	07-29-99	0740	350	0	--	--	--	--

Table 4. Quality-assurance data associated with *Escherichia coli* samples collected in the Kankakee and Lower Wabash River Watershed in Indiana, June–September 1999—Continued

Site number	Date	Time	Concentration of <i>Escherichia coli</i>					Natural log percent difference between environmental and duplicate samples
			Environmental sample (colonies per 100 milliliters)	Filter blank (colonies per 100 milliliters)	Process blank (colonies per 100 milliliters)	Field blank (colonies per 100 milliliters)	Concurrent duplicate (colonies per 100 milliliters)	
26	08-03-99	0930	230	0	--	--	--	--
	08-10-99	0900	700	0	--	--	--	--
	08-17-99	0855	K600	0	--	--	800	-29
	08-24-99	0815	440	0	0	--	--	--
	08-31-99	0815	250	0	--	--	--	--
27	08-03-99	1010	110	0	--	--	--	--
	08-10-99	0925	110	0	--	--	--	--
	08-17-99	0930	170	0	--	--	--	--
	08-24-99	0855	110	0	--	--	--	--
	08-31-99	0900	160	0	--	--	--	--
28	08-03-99	1100	36	0	--	--	--	--
	08-10-99	1000	270	0	--	--	--	--
	08-17-99	0955	93	0	--	--	--	--
	08-24-99	0940	170	0	--	--	--	--
	08-31-99	1000	84	0	--	--	--	--
29	08-03-99	1200	40	0	--	--	--	--
	08-10-99	1040	36	0	--	--	43	-18
	08-17-99	1030	K43	0	--	--	--	--
	08-24-99	1025	K17	0	--	--	--	--
	08-31-99	1045	21	0	--	--	--	--
30	06-28-99	1330	8,000	0	4	--	--	--
	07-06-99	1215	280	0	0	--	230	20
	07-12-99	1130	K45	0	--	--	--	--
	07-19-99	1110	1,200	0	--	--	--	--
	07-26-99	1105	K67	0	--	--	--	--

Table 4. Quality-assurance data associated with *Escherichia coli* samples collected in the Kankakee and Lower Wabash River Watershed in Indiana, June–September 1999—Continued

Site number	Date	Time	Concentration of <i>Escherichia coli</i>					Natural log percent difference between environmental and duplicate samples
			Environmental sample (colonies per 100 milliliters)	Filter blank (colonies per 100 milliliters)	Process blank (colonies per 100 milliliters)	Field blank (colonies per 100 milliliters)	Concurrent duplicate (colonies per 100 milliliters)	
31	08-05-99	0915	K43	0	--	--	--	--
	08-12-99	0900	K68	0	--	--	--	--
	08-19-99	0915	K45	0	--	--	K47	-4
	08-26-99	0840	K18	0	--	--	--	--
	09-02-99	0835	K46	0	--	--	--	--
32	08-05-99	0955	170	0	--	--	--	--
	08-12-99	0925	440	0	--	--	--	--
	08-19-99	0935	180	0	--	--	--	--
	08-26-99	0912	K250	0	--	--	--	--
	09-02-99	0900	130	0	--	--	--	--
33	06-28-99	1205	690	0	--	--	--	--
	07-06-99	1120	470	0	--	--	--	--
	07-12-99	1050	K250	0	--	--	--	--
	07-19-99	1030	2,000	0	2	--	2,200	-10
	07-26-99	1010	K580	0	0	--	--	--
34	08-05-99	1030	800	0	1	--	K880	-10
	08-12-99	0940	660	0	0	--	--	--
	08-19-99	1000	470	0	0	--	--	--
	08-26-99	0938	190	0	0	--	--	--
	09-02-99	0930	490	0	--	--	--	--
35	08-02-99	1410	170	0	0	--	--	--
	08-09-99	1235	470	0	0	--	--	--
	08-16-99	1210	230	0	1	--	--	--
	08-23-99	1240	620	0	--	0	--	--
	08-30-99	1211	220	0	1	--	--	--

Table 4. Quality-assurance data associated with *Escherichia coli* samples collected in the Kankakee and Lower Wabash River Watershed in Indiana, June–September 1999—Continued

Site number	Date	Time	Concentration of <i>Escherichia coli</i>					Natural log percent difference between environmental and duplicate samples
			Environmental sample (colonies per 100 milliliters)	Filter blank (colonies per 100 milliliters)	Process blank (colonies per 100 milliliters)	Field blank (colonies per 100 milliliters)	Concurrent duplicate (colonies per 100 milliliters)	
36	08-02-99	1345	K26	0	--	--	--	--
	08-09-99	1210	160	0	--	--	--	--
	08-16-99	1155	83	0	--	--	--	--
	08-23-99	1221	140	0	--	--	190	-31
	08-30-99	1145	97	0	--	--	--	--
37	08-04-99	1030	280	0	--	--	--	--
	08-11-99	0955	380	0	--	--	--	--
	08-18-99	1030	340	0	--	--	--	--
	08-25-99	1002	210	0	0	--	220	-5
	09-01-99	1040	780	0	--	--	--	--
38	08-04-99	0855	110	0	--	--	--	--
	08-11-99	0830	230	0	--	--	--	--
	08-18-99	0905	140	0	--	--	--	--
	08-25-99	1044	130	0	--	--	--	--
	09-01-99	0820	87	0	--	0	--	--
39	08-03-99	1340	K16	0	0	--	--	--
	08-10-99	1135	K13	0	0	--	--	--
	08-17-99	1125	K33	0	0	--	--	--
	08-24-99	1140	K4	0	--	--	--	--
	08-31-99	1315	K33	0	0	--	K10	119
40	08-04-99	1145	<1	0	0	--	--	--
	08-11-99	1030	K31	0	0	--	--	--
	08-18-99	1100	<3	0	0	--	--	--
	08-25-99	0920	<3	0	--	--	--	--
	09-01-99	1155	K3	0	0	--	K13	-147

Table 4. Quality-assurance data associated with *Escherichia coli* samples collected in the Kankakee and Lower Wabash River Watershed in Indiana, June–September 1999—Continued

Site number	Date	Time	Concentration of <i>Escherichia coli</i>					Natural log percent difference between environmental and duplicate samples
			Environmental sample (colonies per 100 milliliters)	Filter blank (colonies per 100 milliliters)	Process blank (colonies per 100 milliliters)	Field blank (colonies per 100 milliliters)	Concurrent duplicate (colonies per 100 milliliters)	
41	06-28-99	1003	1,500	0	0	--	--	--
	07-06-99	1150	480	0	--	--	--	--
	07-12-99	1037	230	0	0	0	--	--
	07-19-99	1100	120	0	--	--	--	--
	07-26-99	1135	K92	0	--	--	--	--
42	06-28-99	0915	270	0	--	0	500	-62
	07-06-99	1055	K66	0	--	--	--	--
	07-12-99	0958	110	0	--	--	--	--
	07-19-99	1022	230	0	--	0	--	--
	07-26-99	1020	210	0	--	--	--	--
43	08-02-99	1235	45	0	--	--	30	41
	08-09-99	1125	53	0	--	--	--	--
	08-16-99	1105	59	0	--	--	--	--
	08-23-99	1140	97	0	0	--	--	--
	08-30-99	1055	K7	0	--	--	--	--
44	08-02-99	1055	20	0	--	0	--	--
	08-09-99	1015	30	0	--	--	--	--
	08-16-99	0950	24	0	--	--	--	--
	08-23-99	1115	39	0	--	0	26	41
	08-30-99	1102	K36	0	--	--	--	--
45	08-02-99	1300	32	0	0	--	--	--
	08-09-99	1140	34	0	--	--	--	--
	08-16-99	1125	47	0	--	--	--	--
	08-23-99	1250	32	0	--	--	--	--
	08-30-99	1259	K13	0	--	--	--	--

Table 4. Quality-assurance data associated with *Escherichia coli* samples collected in the Kankakee and Lower Wabash River Watershed in Indiana, June–September 1999—Continued

		Concentration of <i>Escherichia coli</i>						Natural log percent difference between environmental and duplicate samples
Site number	Date	Time	Environmental sample (colonies per 100 milliliters)	Filter blank (colonies per 100 milliliters)	Process blank (colonies per 100 milliliters)	Field blank (colonies per 100 milliliters)	Concurrent duplicate (colonies per 100 milliliters)	
46	08-02-99	1200	64	0	--	--	--	--
	08-09-99	1055	48	0	0	0	--	--
	08-16-99	1040	80	0	--	--	--	--
	08-23-99	1200	250	0	0	--	--	--
	08-30-99	1208	59	0	0	--	--	--
47	08-02-99	1415	K1	0	--	--	--	--
	08-09-99	1215	K10	0	--	--	--	--
	08-16-99	1300	42	0	0	--	--	--
	08-23-99	1340	K8	0	--	--	--	--
	08-30-99	1425	K36	0	--	0	K15	88
48	08-04-99	0930	K15	0	--	--	--	--
	08-11-99	0900	K43	0	--	--	K49	-13
	08-18-99	0915	K33	0	--	--	--	--
	08-25-99	1122	K15	0	--	--	--	--
	09-01-99	0905	K64	0	--	--	--	--
49	08-02-99	1135	780	0	--	0	--	--
	08-09-99	1040	340	0	--	0	--	--
	08-16-99	1030	520	0	--	0	--	--
	08-23-99	1020	970	0	--	--	--	--
	08-30-99	0930	220	0	--	--	--	--
50	08-03-99	0900	310	0	--	--	--	--
	08-10-99	0840	220	0	--	--	--	--
	08-17-99	0915	420	0	--	--	--	--
	08-24-99	0915	57	0	--	--	110	-66
	08-31-99	1025	K13	0	--	--	--	--

Table 4. Quality-assurance data associated with *Escherichia coli* samples collected in the Kankakee and Lower Wabash River Watershed in Indiana, June–September 1999—Continued

Site number	Date	Time	Concentration of <i>Escherichia coli</i>					Natural log percent difference between environmental and duplicate samples
			Environmental sample (colonies per 100 milliliters)	Filter blank (colonies per 100 milliliters)	Process blank (colonies per 100 milliliters)	Field blank (colonies per 100 milliliters)	Concurrent duplicate (colonies per 100 milliliters)	
51	08-03-99	0820	K33	0	--	--	--	--
	08-10-99	0800	180	0	--	--	--	--
	08-17-99	0825	94	0	--	--	98	-4
	08-24-99	0815	190	0	1	--	--	--
	08-31-99	0927	240	0	--	--	--	--
52	08-03-99	1250	97	0	0	--	--	--
	08-10-99	1045	160	0	--	--	--	--
	08-17-99	1250	72	0	--	--	--	--
	08-26-99	0830	67	0	--	--	--	--
	08-31-99	1355	42	0	0	--	75	-58
53	08-03-99	1010	73	0	--	--	--	--
	08-10-99	0925	110	0	0	--	90	20
	08-17-99	1030	110	0	--	--	--	--
	08-24-99	1100	140	0	--	--	--	--
	08-31-99	1118	K41	0	--	--	--	--
54	08-03-99	1120	K15	0	--	--	K92	-181
	08-10-99	1010	K9	1	--	--	--	--
	08-17-99	1130	K4	0	0	--	--	--
	08-24-99	1130	K22	0	--	--	--	--
	08-31-99	1245	K30	0	--	--	--	--
55	08-05-99	0745	290	0	--	--	--	--
	08-12-99	0715	280	0	0	--	--	--
	08-19-99	0745	670	0	1	--	--	--
	08-26-99	0915	730	0	--	--	--	--
	09-02-99	0748	380	0	--	--	--	--

Table 4. Quality-assurance data associated with *Escherichia coli* samples collected in the Kankakee and Lower Wabash River Watershed in Indiana, June–September 1999—Continued

Site number	Date	Time	Concentration of <i>Escherichia coli</i>					Natural log percent difference between environmental and duplicate samples
			Environmental sample (colonies per 100 milliliters)	Filter blank (colonies per 100 milliliters)	Process blank (colonies per 100 milliliters)	Field blank (colonies per 100 milliliters)	Concurrent duplicate (colonies per 100 milliliters)	
56	08-05-99	0900	240	0	1	--	--	--
	08-12-99	0800	K100	0	--	--	--	--
	08-19-99	0900	K31	0	--	--	K38	-20
	08-26-99	1000	<1	0	--	--	--	--
	09-02-99	0840	K8	0	--	--	--	--
57	08-04-99	1415	56	0	0	--	--	--
	08-11-99	1120	32	0	--	--	K57	-58
	08-18-99	1315	K26	0	0	--	--	--
	08-25-99	1245	K64	0	--	--	--	--
	09-01-99	1320	K4	0	0	--	--	--
58	08-04-99	1115	K14	0	--	--	K8	56
	08-11-99	0915	K4	8	0	--	--	--
	08-18-99	1040	K23	0	--	0	--	--
	08-25-99	1020	K61	0	0	--	--	--
	09-01-99	1043	K3	0	--	--	--	--