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Sanitary Quality of Surface Water During Base-Flow Conditions in the Municipality of Caguas, Puerto Rico, 2014–15: A Comparison With Results From a Similar 1997–99 Study

Scientific Investigations Report 2017–5045

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

Cover. Looking northeast toward the Caguas valley, Puerto Rico. Photograph by Francisco Maldonado, U.S. Geological Survey.

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.4047	hectare (ha)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
quart (qt)	0.0009464	milliliter (mL)
cubic inch (in^3)	0.00001639	milliliter (mL)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
ounce (oz)	0.028.35	milligram(mg)
pound (lb)	0.4536	kilogram (kg)

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

$$°F = (1.8 \times °C) + 32.$$

Datum

Vertical coordinate information is referenced to local mean sea level.

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

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

Supplemental Information

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L) or nanograms per liter (ng/L)

Abbreviations

CFWSC	Caribbean-Florida Water Science Center
$\delta^{15}N$	delta nitrogen-15
$\delta^{18}O$	delta oxygen-18
GPS	global positioning system
HHPP	human health and pharmaceuticals product
N	nitrogen
NO_2	nitrite
NO_3	nitrate
NWIS	National Water Information System
NWQL	National Water Quality Laboratory
O	oxygen
PREQB	Puerto Rico Environmental Quality Board
QA/QC	quality-assurance and quality-control
RPD	relative percent difference
RSIL	Reston Stable Isotope Laboratory
USGS	U.S. Geological Survey

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By Jesús Rodríguez-Martínez and Senén Guzmán-Ríos

Abstract

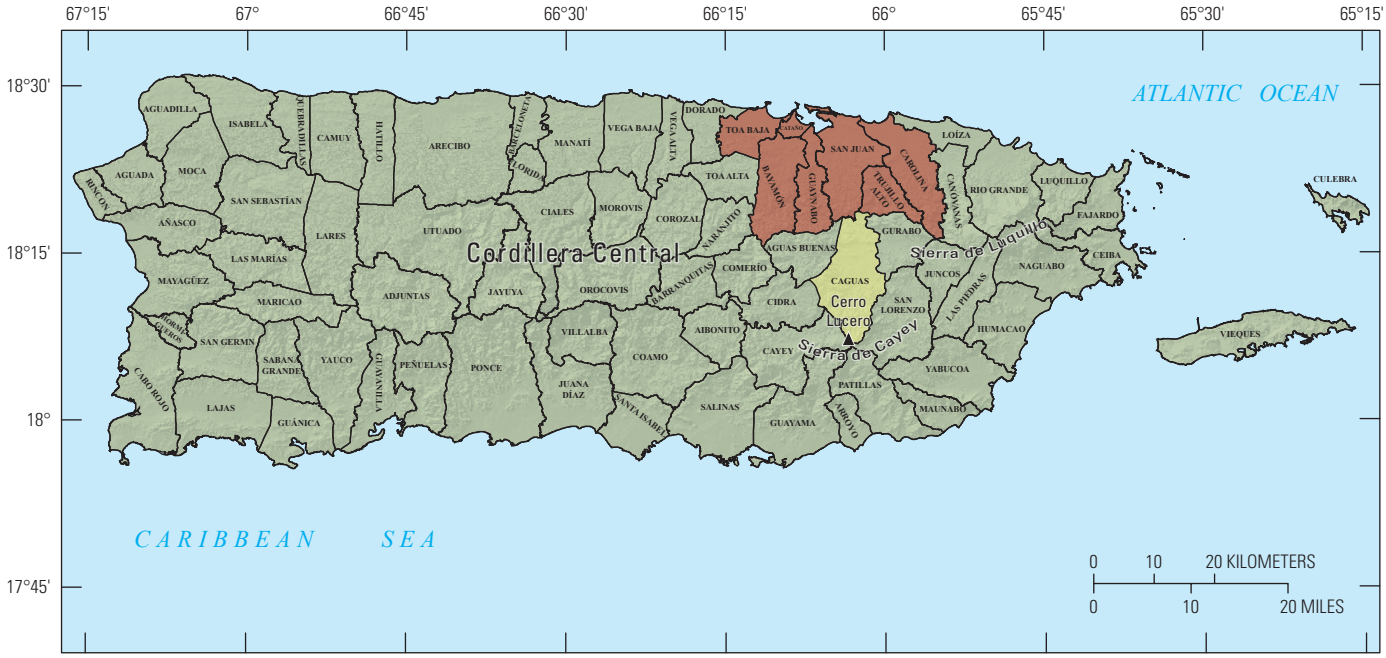
A study was conducted in 2014–15 by the U.S. Geological Survey (USGS), in cooperation with the Municipality of Caguas, to determine if changes in the stream sanitary quality during base-flow conditions have occurred since 1997–99, when a similar study was completed by the USGS. Water samples were collected for the current study during two synoptic surveys in 2014 and 2015. Water samples were analyzed for fecal and total coliform bacteria, nitrate plus nitrite as nitrogen, nitrogen and oxygen isotopes of nitrate, and human health and pharmaceutical products. Water sampling occurred at 39 stream locations used during the 1997–99 study by the USGS and at 11 additional sites. A total of 151 stream miles were classified on the basis of fecal and total coliform bacteria results.

The overall spatial pattern of the sanitary quality of surface water during 2014–15 is similar to the pattern observed in 1997–99 in relation to the standards adopted by the Puerto Rico Environmental Quality Board in 1990. Surface water at most of the water-sampling sites exceeded the current standard for fecal coliform of 200 colonies per 100 milliliters adopted by the Puerto Rico Environmental Quality Board in 2010. The poorest sanitary quality was within the urban area of the Municipality of Caguas, particularly in urban stream reaches of Río Caguitas and in rural and suburban reaches bordered by houses in high density that either have inadequate septic tanks or discharge domestic wastewater directly into the stream channels. The best sanitary quality occurred in areas having little or no human development, such as in the wards of San Salvador and Beatriz to the south and southwest of Caguas, respectively. The concentration of nitrate plus nitrite as nitrogen ranged from 0.02 to 9.0 milligrams per liter, and did not exceed the U.S. Environmental Protection Agency drinking-water standard for nitrate as nitrogen of 10 milligrams per liter. The composition of nitrogen and oxygen isotopes of nitrate indicates that the origin of nitrate in the streams is most likely animal and human waste. A baseline was established for the concentrations of selected human health and pharmaceutical products at stations in some of the streams within the Municipality of Caguas. Thirty-eight human health and pharmaceutical products were present at or above the measurement detection level.

Introduction

The Autonomous Municipality of Caguas (referred to herein as the Municipality of Caguas) is located south of San Juan at the eastern end of the Cordillera Central mountain range and between the Sierra de Cayey and Sierra de Luquillo minor mountain ranges (fig. 1). Caguas, with an area of 58.7 square miles (mi^2) and a population of about 143,000 in 2015, is part of the larger San Juan metropolitan area. The average population density is about 2,394 persons per mi^2. The maximum land surface altitude in the Municipality of Caguas (2,887 feet [ft] above mean sea level) is at Cerro Lucero (fig. 1).

A study conducted during 1997–99 by the U.S. Geological Survey (USGS), in cooperation with the Municipality of Caguas, classified the streams within the municipal territory according to their sanitary quality during base-flow conditions (Gómez-Gómez and others, 2001). The classification of sanitary quality was based on whether the concentration of fecal coliform and total coliform exceeded the prevalent standards of the Puerto Rico Environmental Quality Board (PREQB) for these parameters during 1997–99 in successive samples (Junta de Calidad Ambiental de Puerto Rico, 1990). Water samples from 40 stream sites within the Municipality of Caguas were analyzed for fecal coliform bacteria. The study indicated that 28 percent of stream miles analyzed within the territory were classified as having poor sanitary quality. Only 9.6 percent of the total stream miles classified were of good sanitary quality; the remaining 62.4 percent were classified as having fair or acceptable sanitary water quality. Approximately 26 stream miles (mi) out of a total of 163 mi (about 16 percent) were not classified because of insufficient data.



Base modified from U.S. Geological Survey digital data

Figure 1. Puerto Rico showing the Caguas and San Juan metropolitan areas, including boundaries of the municipalities (on plate).

As part of the 1997–99 study, the surface waters within the Municipality of Caguas were classified in terms of their sanitary quality according to the water-quality standards for surface waters in Puerto Rico established and implemented by the PREQB (Junta de Calidad Ambiental de Puerto Rico, 1990). The water-quality standards implemented by PREQB are based on the designated use of the surface waters; for example, fishing, raw water source for public-supply, and secondary contact for recreation, among other uses. All perennial fresh surface waters in Puerto Rico inland of their estuaries are classified as Class SD waters. In the 1997–99 study, the sanitary quality standard for Class SD surface water according to the PREQB (Junta de Calidad Ambiental de Puerto Rico, 1990) was based on the fecal coliform or total coliform indicator bacteria concentration as follows: the geometric mean concentration of at least five samples in sequential order shall not exceed 10,000 colonies per 100 milliliters (mL) for total coliform bacteria or 2,000 colonies per 100 mL for fecal coliform bacteria, and not more than 20 percent of the samples (1 in a set of 5) shall exceed 400 colonies per 100 mL of fecal coliform bacteria (Junta de Calidad Ambiental de Puerto Rico,1990).

During 1997–99, the contamination sources that affected stream sanitary quality during base-flow conditions were distinct for urban and rural areas (Gómez-Gómez and others, 2001). In urban areas, probable major sources of fecal contamination were the illegal discharge of sewage to stormwater drains, overflows from sewer mains into the stormwater drains because of clogged mains, ruptured sewer mains, and seepage from sewer mains into the local aquifer. In rural areas, major sources of fecal contamination included gray-water discharge from residential and commercial establishments along stream channels, septic tank seepage or overflows, fecal contamination directly into streams from unfenced livestock, and runoff from restrained livestock pens near stream courses. Another potential source of fecal contamination considered during the 1997–99 study was runoff and groundwater seepage from the municipal landfill at Barrio Turabo (fig. 2; Gómez-Gómez and others, 2001).

Gómez-Gómez and others (2001) also delineated the potential contaminant sources from unsewered rural communities in proximity to stream courses, particularly along stream segments with fecal coliform concentrations below 2,000 colonies per 100 mL. It is likely that the indicator bacteria might have become affected by household wastewater discharges, rendering them unable to grow and form colonies because of structural or metabolic changes associated with exposure to untreated wastes (American Public Health Association, American Public Works Association and Water Environment Federation, 1998). Housing communities bordering the riparian zone or dense housing developments, generally having one or more housing units per 1/5th acre and located within 300 feet (ft) of stream courses are potential sources of fecal contamination to streams from “gray-water” discharge and septic tank seepage.

The Municipality of Caguas adopted and implemented measures to improve the sanitary quality of streams and to comply with the Commonwealth of Puerto Rico State and Federal standards at those streams for which the study by Gómez-Gómez and others (2001) indicated high fecal contamination during 1997–99. After a 15-year period in which the population increased from 140,500 to 142,900 (U.S. Census Bureau, 2012), the Municipal Government of Caguas sought to determine the

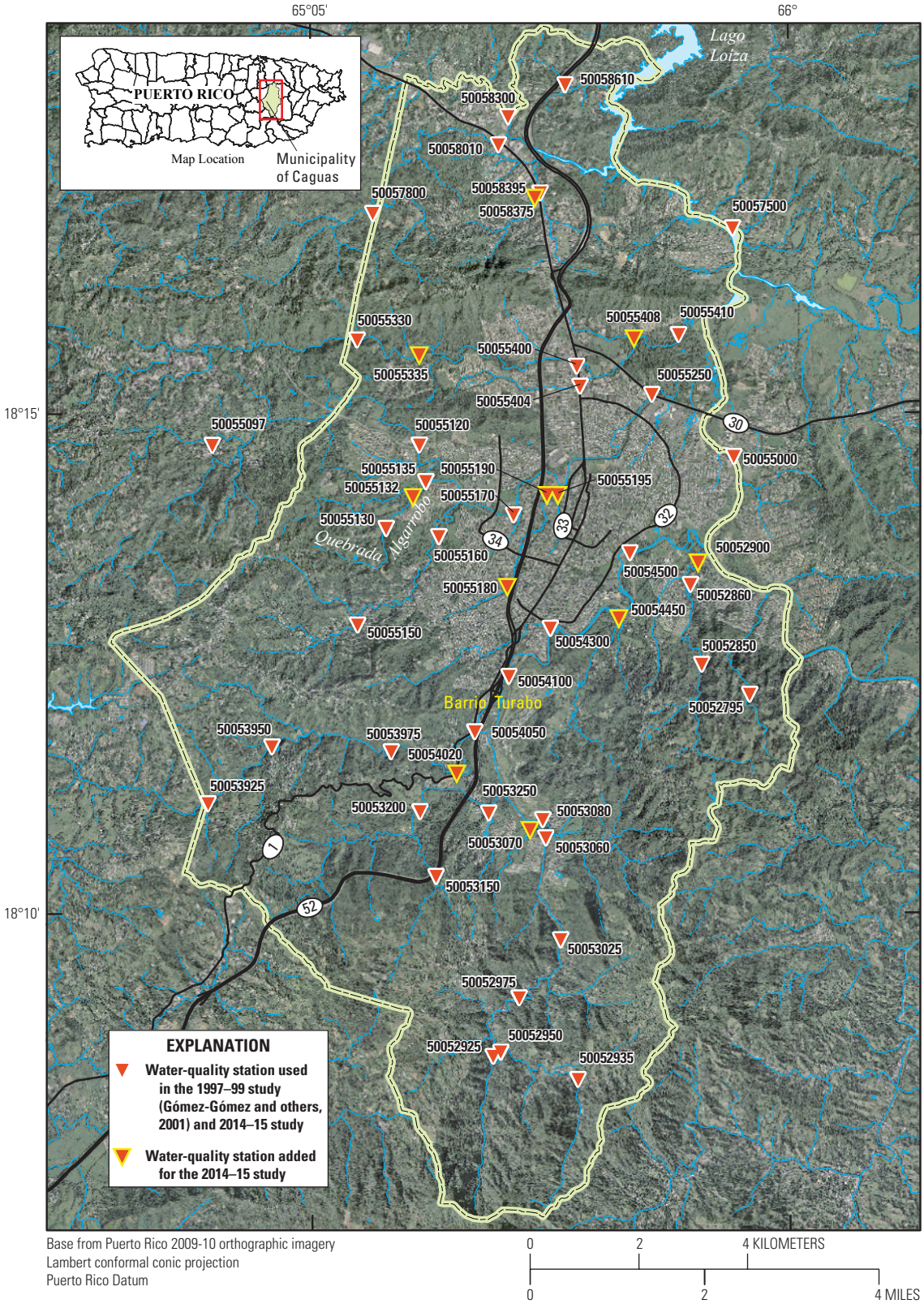


Figure 2. Caguas showing sampling sites with identification numbers presented in appendix 1.

efficacy of the implemented remediation measures, including the extension of sewer service to previously unserved areas. Therefore, the Municipality of Caguas asked the USGS to reassess the sanitary quality of the stream sites within the municipality during base-flow conditions, including the stream sites used in the first study and nine additional stream sites.

In this second USGS study, conducted during 2014–15 in cooperation with the Municipality of Caguas, the sampling and analysis were expanded to include additional biological, chemical, and isotopic indicators to help identify sources of contaminants, other than fecal material, that might degrade the sanitary quality of the streams. The stricter classification system adopted by the Puerto Rico Environmental Quality Board in 2010 (Junta de Calidad Ambiental de Puerto Rico, 2010) was used in conjunction with that used in the 1997–99 study (Junta de Calidad Ambiental de Puerto Rico, 1990). The Municipality of Caguas will use the results of the 2014–15 study to identify the stream reaches not in compliance with the Commonwealth and Federal standards of sanitary quality, despite the measures implemented after the 1997–99 study. These sites may require more aggressive remediation measures in order to reach compliance with water-quality standards. The results of the 2014–15 study will enable the Municipality of Caguas to adopt more effective corrective measures than those implemented after the 1997–99 study. The municipal authorities of Caguas are also concerned with the possible presence of human health and pharmaceutical products (HHPPs) in surface waters of the municipality and their potential threat to human health. Therefore, in addition to assessment of biological, chemical, and isotopic parameters, the Municipality of Caguas requested that the USGS sample for the presence of HHPPs in surface waters. The detectable HHPPs are to serve as baseline data, but were not used in the classification of the sanitary quality of the surface waters in the Municipality of Caguas.

Purpose and Scope

This report documents the sanitary quality of surface water during base-flow conditions in the Municipality of Caguas, Puerto Rico, during 2014–15 and provides a comparison with results from a similar study conducted during 1997–99. The 2014–15 study consisted of two synoptic surveys completed during base-flow conditions. Water samples were collected and analyzed for fecal and total coliform bacteria, concentrations of nitrate (NO_3) plus nitrite (NO_2) as nitrogen, nitrogen (N) and oxygen (O) isotope ratios of NO_3, and HHPPs. Although the synoptic surveys were conducted in streams that have their headwaters outside the municipal boundaries, most of the sampling was conducted within the Municipality of Caguas. The 2014–15 study area was slightly larger than the 1997–99 study area of 73.6 mi^2 because of the addition of the new stream sites. Neither the HHPPs data nor the NO_3 plus NO_2 data were used to classify the surface waters within the Municipality of Caguas. The concentrations of NO_3 plus NO_2 in combination with the N and O isotopes of NO_3 provide insights to the probable sources of nitrogen found in surface waters of the Municipality of Caguas.

Methods of Study

A range of weather conditions occurred during the 2014–15 sampling program, and may have affected the water-quality constituents and characteristics considered. The first sampling period was in August 2014 during a base-flow period following a major storm and subsequent high streamflow event. The second sampling period was in March 2015, during the annual dry season when base-flow conditions prevailed in the streams.

During the 2014–15 study, sanitary quality was classified according to the revised and more rigorous standards adopted in 2010 by the PREQB (Junta de Calidad Ambiental de Puerto Rico, 2010); the standard for fecal coliform changed from 2,000 colonies per 100 mL, implemented by the PREQB in 1990 and used in the 1997–99 study, to 200 colonies per 100 mL adopted by the PREQB in 2010. In order to compare the 2014–15 results with those of the 1997–99 study, the sanitary quality of the surface waters within the Municipality of Caguas in the 2014–15 study were also classified according to the standards for surface waters in Puerto Rico established by the PREQB in 1990 (Junta de Calidad Ambiental de Puerto Rico, 1990) used in the 1997–99 study (Gomez-Gomez and others, 2001).

Water samples for fecal and total coliform bacteria, and NO_3 plus NO_2, were analyzed from a total of 50 sampling sites at streams with drainage into or within the Municipality of Caguas in August 2014 and March 2015. This total consists of 39 of the 40 sites used in the 1997–99 study and 11 new sites added for the 2014–15 study (appendix 1), for a net increase of 10 sites (fig. 2 and plate 1). Three of the 11 new sampling sites were either in first- or second-order tributaries of Río Caguitas, Río Bairoa, and Río Cañas, which were not sampled for fecal coliform in the 1997–99 study (station 50058395 at Río Cañas, station 50055408 at Río Bairoa, and station 50055195 at Río Caguitas). The remaining eight new sampling sites were at streams already sampled during the 1997–99 study, and the objective of their addition was to more precisely define the spatial variation in sanitary quality. The two unused sites from the 1997–99 study, unsampled because of access problems, were Rio Caguitas at Highway 777 (station 50055092) and Tributary at Barrio Borinquen to Rio Turabo at Highway 765 (station 50053085) (Gomez-Gomez and others, 2001). In order to be consistent and to be able to compare 2014–15 results with 1997–99 results, samples were obtained during stream base-flow periods under two hydrologic conditions: (1) near the annual stream low-flow discharge and (2) during base-flow conditions after a rainfall event. Water-quality data obtained during these flow regimes were interpreted following methods of Gomez-Gómez and others (2001) to classify the stream courses within or with drainage into the Municipality of Caguas. Fecal contamination during stream base-flow conditions is principally from sources that either discharge directly to stream channels or enter stream channels from sources adjacent to streambanks.

At nine sites, water samples were also collected in March 2015 to determine the concentration of NO_3 plus NO_2 as N, and the ratio in delta (δ) notation of N ($^{15}N/^{14}N$) and O ($^{18}O/^{16}O$) isotopes of NO_3. These data were used to determine the probable sources of N in streams (Clark and Fritz, 1997; Kendall, 1998). Samples for HHPPs were collected at eight sites in March 2015 close to a water-supply intake or wastewater treatment plant.

The fecal and total coliform bacteria concentrations were determined at the USGS Caribbean-Florida Water Science Center (CFWSC) field laboratory or the CFWSC laboratory in Guaynabo, Puerto Rico. Nitrate plus nitrite concentrations were determined at the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado (http://nwql.usgs.gov). The ratios of N and O isotopes of NO_3 were determined at the USGS Reston Stable Isotope Laboratory (RSIL) in Reston, Virginia (http://isotopes.usgs.gov//lab/methods.html). HHPPs were analyzed at the NWQL (http://nwql.usgs.gov); the methods used for analysis of individual products are described at https://www.nemi.gov/home/.

Field Methods

Raw water samples were collected at each site following the procedures established in the U.S. Geological Survey National Field Manual for the Collection of Water Quality Data (U.S. Geological Survey, variously dated). Sampling for total and fecal coliform was conducted at all stream sites during base-flow conditions using the "hand-dip" method (U.S. Geological Survey, 1989). This method involves dipping a sterile wide-mouth 99-mL plastic bottle 1 to 2 inches (in.) below the water surface with the bottle opening pointed slightly upward towards the current. The locations of the sampling sites were recorded using a global positioning system (GPS) device to ensure that the data were consistently collected from the same location.

Duplicate samples and equipment and field blanks for all chemical and bacteriological analyses were collected for each parameter (not less than 10 percent of the total samples) at sampling sites selected randomly, during each sampling run, to quantify the total variability associated with the sampling and analytical methods. The duplicate sample was collected at the same time and from the same location as the primary sample.

Raw-water samples (106 environmental samples, 6 duplicates, 1 equipment blank at the beginning of the project and 1 at the end, and 6 field blanks) were analyzed for nitrate plus nitrite. Total and fecal coliform was also analyzed from raw water samples (106 environmental and 12 duplicates), the equipment blanks (1 at the beginning and 1 at the end) and 6 field blanks, using the USGS CFWSC mobile laboratory. The $\delta^{15}N$ and $\delta^{18}O$ of NO_3 were analyzed in raw surface-water samples (7 environmental samples and 1 duplicate sample), and in the equipment blanks (1 collected at the beginning of the project and 1 field blank). HHPPs were determined in 5 environmental samples, 1 duplicate sample, 1 equipment blank collected at the beginning of the project, and 1 field blank. Measurements of instantaneous discharge were made during each sampling, except where conditions were unstable or stagnant. The data used in this report can be accessed through the USGS National Water Information System (NWIS; U.S. Geological Survey, 2017).

Analytical Techniques

The analytical procedure used to measure fecal and total coliform bacteria concentrations was the membrane-filter method immediate incubation test in accordance with standard USGS protocols (U.S. Geological Survey, 1989). Dilution ratios for membrane filtration analyses at each station were prepared to maximize the probability of obtaining about 20 to 60 colonies per filter for fecal coliform bacteria and 20 to 80 colonies per filter for total coliform bacteria. If colony counts were not within the ideal range, concentrations were reported as nonideal. If the number of colonies per 100 mL from the highest dilution ratio of three sample volumes filtered at a station was above the ideal plate count, the concentration was indicated as estimated from a nonideal high plate count. If the number of colonies per 100 mL from the lowest dilution ratio of three sample volumes filtered at a station was below the ideal plate count, the concentration was indicated as estimated from a nonideal low plate count. The samples were processed and incubated immediately after collection using the mobile field laboratory, or when the field laboratory was not available, samples were preserved in an ice chest at 1 to 4 °C and processed at the CFWSC laboratory in Guaynabo, Puerto Rico.

The quality-assurance and quality-control (QA/QC) protocols for bacteriological analyses are the same as those used in the 1997–99 study and are listed here as in Gomez-Gómez and others (2001): (a) incubation of sterile buffered water in culture media at the CFWSC laboratory in Guaynabo, Puerto Rico, as a primary check for the sterile conditions of buffer, media, and filters; (b) field blanks to verify sterile conditions of field equipment; and (c) processing of duplicate samples as a check on dilution procedure and variability of bacteriological concentrations resulting from dip sampling. Most QA/QC samples, on average, consisted of laboratory or field blanks for parts (a) and (b). Duplicate sample dilutions were only two per sampling run. Overall, the result for parts (a) and (b) should be negative. In part (a), if development of fecal and coliform bacteria colonies occurs, the media sample petri dishes and buffered-water dilution bottles are not acceptable for use. In part (b), positive results are a reason to review analytical results of samples obtained between negative QA/QC (before and after the positive blank) for suspect data; that is, high counts or substantial discrepancy between the number of colonies developed for sample dilutions with ideal and nonideal counts. Anomalous counts of bacteria are not used in the analysis. Relative percent differences (RPDs) of primary and duplicate samples were calculated as follows:

$$RPD = (S1 - S2)/[(S1 + S2)/2] \times 100,$$

where S1 and S2 are the colony counts of the primary and duplicate samples, respectively.

Sampling Sites and Stream Classification

The relative classification of sampling stations and corresponding streams in the 2014–15 study using the Puerto Rico Water Quality Standards for fecal coliform established in 1990 by the PREQB (Junta de Calidad Ambiental de Puerto Rico, 1990) follows the same rationale as the 1997–99 study by Gómez-Gómez and others (2001).

Sampling sites with fecal coliform bacteria concentrations greater than 2,000 colonies per 100 mL for both sampling dates were considered poor. Sampling sites with fecal coliform bacteria concentrations equal to or greater than 2,000 colonies per 100 mL on one of the sampling dates, but below 2,000 colonies per 100 mL on the other sampling date were classified as fair. Sampling sites with fecal coliform bacteria concentrations equal to or less than 2,000 colonies per 100 mL on both sampling dates were classified as acceptable. If samples on both dates had fecal coliform bacteria concentrations below 200 colonies per 100 mL, a classification of good was assigned.

Stream segment classification was extended upstream and downstream from a given sampling site as follows. If another sampling site was established upstream and (or) downstream within the same order stream and the results were comparable, the same classification was given for the entire stream segment between both sampling sites; if the upstream site and (or) downstream site was classified differently, the classification was extended to the midpoint of the segment; and if no other sampling site was located upstream, the same classification was extended upstream not more than 0.6 mi along the main trunk of the stream.

For a stream segment, an upstream reach greater than 0.6 mile from the sampling site, including the segment tributaries, the same classification was assigned but using the term "presumed." If no other sampling station was established downstream, the same classification was used up to a distance of 0.6 mi along the main channel of the stream (same stream order), with the qualification of "presumed" assigned downstream of the 0.6-mi distance. The prefix "presumed" was also used in the classification of several streams having drainage areas of less than 3 mi^2. For these streams, the classification was based on sampling results obtained from streams draining adjacent watersheds having similar land-use conditions as determined from field inspections.

The "presumed" good classification was not assigned to any stream (or tributary) in which fecal coliform data were not obtained, given the low incidence of good or presumed good classifications in the study area; only 4 of 74 samples met the requirements for the good classification in the previous study (Gómez-Gómez and others, 2001). Within the city of Caguas, an exception was made whereby the stream classification of presumed poor was extended upstream to the urban limits. This extension was justified, because of the 19 sampling sites established within the urban reaches of streams, 10 had fecal coliform concentrations classified as poor.

The classification of sampling sites according to the water-quality standards revised by PREQB (Junta de Calidad Ambiental de Puerto Rico, 2010) was done in a manner similar to that of Gomez-Gomez and others (2001) in the 1997–99 study but using only the poor, fair, and good classifications. Sampling sites having fecal coliform bacteria concentrations greater than 200 colonies per 100 mL for both sampling dates were considered poor. Sampling sites at which fecal coliform bacteria concentrations were greater than 200 colonies per 100 mL on one of the sampling dates, but equal or below 200 colonies per 100 mL on the other sampling date were classified as fair. Sampling sites with fecal coliform bacteria concentrations equal to or below 200 colonies per 100 mL on both sampling dates were classified as good.

Sanitary Quality of Surface Water During Base-Flow Conditions

The interpretation of the results obtained during this study assumes that, as in the 1997–99 study, streamflow during low-flow conditions is derived from groundwater discharge, and thus, it is reasonable to consider that the fecal matter noted during stream base-flow conditions originates primarily from sources discharging directly into the streams or from groundwater sources. It is also assumed that two samples obtained several months apart during low-flow recession periods at numerous locations throughout the watersheds are sufficient to qualitatively define the sanitary quality of the surface water within the Municipality of Caguas. Based on these assumptions, fecal coliform bacteria concentration data from the stream sampling sites and the Lago Loíza reservoir sampling site were used to characterize the sanitary quality of 151 mi of perennial streams within the Municipality of Caguas.

The concentrations of fecal and total coliform bacteria, NO_3 plus NO_2 as N, the instantaneous discharge at each sampling site, and the sanitary quality classification of each sampling station are summarized in appendix 1, and data are available through the USGS NWIS (U.S. Geological Survey, 2017). All bacteriological results were considered in the analysis. Results from duplicate samples were within 15 percent of each other, which is common for duplicate samples having fecal coliform concentrations in the range of 100 to a few thousand colonies per 100 mL (Gómez-Gómez and others, 2001).

On the basis of the PREQB standards implemented in 1990, for this study, 4 of the sites were classified as good, 25 were acceptable, 10 were fair, and 11 were poor. About 151 stream miles were classified (plate 1, table 1). The stream miles in each classification from the 1997–99 study by Gómez-Gómez and others (2001) are included in table 1 for the purpose of comparison.

On the basis of the PREQB revised standards implemented in 2010, for this study, 6 sites were classified as

good, 12 were fair, and 32 were poor (table 2). The substantial increase in the number of sampling sites ranked as poor is a result of the much stricter standards in water quality adopted by the PREQB in 2010 (Junta de Calidad Ambiental de Puerto Rico, 2010). Four stations that were ranked good according to the 1990 standards were also ranked good according to the 2010 standards. Additionally, two sites that were ranked as acceptable according to the 1990 standards were ranked good according to the 2010 standards. The stations ranked as good are those at the Rio Turabo in the Barrio San Salvador (50052925), at Quebrada de las Quebradillas in the Barrio Beatriz (50053950, 50053925) and Quebrada Algarrobo in Barrio Cañabón (50055132). The barrios (wards) of San Salvador and Beatriz are distant from the Caguas urban area and have a much lower population density than the rest of the Municipality of Caguas (plate 1).

The stream miles classified during the 2014–15 study (151 mi) exceeded those classified by Gómez-Gómez and others (2001) (137 mi). In general, the spatial pattern of sanitary quality during 1997–99 (Gómez-Gómez and others, 2001) remains unchanged in 2014–2015. The poorest sanitary quality is within the urban area of the Municipality of Caguas, particularly in urban reaches of Río Caguitas. The sanitary quality is also poor along stream segments bordered by high-density housing along or close to stream margins that might have inadequate septic tanks or that discharge domestic wastewater directly into the stream channels. The best sanitary quality was in areas having little or no human development, such as in the wards of San Salvador and Beatriz to the south and southwest parts of Caguas, respectively.

The long-term geometric mean of fecal coliform concentration of five sequential samples at 3 of 4 historical

Table 1. Summary of the sanitary quality classification determined for sampling stations according to the Puerto Rico Environmental Quality Board standards of 1990, and stream miles in each classification for 2014–15 in the Municipality of Caguas, Puerto Rico.

[NA, not applicable]

Classification	Number of sites	Percentage of total number of sites	Stream miles	Percentage of total stream miles	Combined percentage of each classification in this study	Combined percentage of each classification in Gómez-Gómez and others (2001)
Poor	11	22	22.9	15.2	23.8	28
Presumed poor	NA	NA	12.9	8.6		
Fair	10	20	7.2	4.8	11.2	18.7
Presumed fair	NA	NA	9.6	6.4		
Acceptable	25	50	28.6	19	54	43.7
Presumed acceptable	NA	NA	52.6	35		
Good	4	8	6.1	4.1	11.1	9.6
Presumed good	NA	NA	10.6	7		

Table 2. Difference in the number of stations with the same sanitary quality classification between the 1997–99 and 2014–15 studies, according to the Puerto Rico Environmental Quality Board standards for 1990.

[PREQB, Puerto Rico Environmental Quality Board; NA, not applicable]

Classification of sanitary quality of surface water	1997–99 stations[1] (Gómez-Gómez and others, 2001; Junta de Calidad Ambiental de Puerto Rico, 1990)	2014–15 stations (current study; Junta de Calidad Ambiental de Puerto Rico, 1990)	2014–15 stations[2] (current study; Junta de Calidad Ambiental de Puerto Rico, 2010)
Poor	10	8	32
Fair	7	5	12
Acceptable	18	21	NA
Good	2	3	6

[1]The 37 stations presented are those sampled during the 1997–99 and 2014–15 studies. The stations not included are (1) the new added stations for the 2014–15 study, (2) two stations not ranked in the 1997–99 study, and (3) two stations from the 1997–99 study not sampled again in 2014–15 because of access limitations.

[2]Classification during the 2014–15 study according to the PREQB standards for 2010.

sampling sites, sampled yearly for the past 20 or more years, exceeded the Puerto Rico sanitary quality standards for Class SD surface waters of 2,000 colonies/100 mL, implemented in 1990. These three sites include Río Bairoa, station 50055400; Río Grande de Loíza, station 50055000; and Río Caguitas, station 50055250 (fig. 3*A*, *B*, *D*, plate 1). The long-term geometric mean of fecal coliform concentration of five sequential samples is mostly below the aforementioned standard at Lago Loíza, station 50057500 (fig. 3*C*, plate 1). The long-term geometric mean of five sequential samples at all four stations was mostly above the PREQB water-quality standard of 200 colonies per 100 mL, adopted in 2010. Sanitary quality results at 3 of the 9 sampling sites added for this study indicated the persistence of poor sanitary quality noted in the 1997–99 study along the urban reaches of Río Caguitas (stations 50055180, 50055190, and 50055195; plate 1). The sanitary quality results at five other new sites (stations 50054020, 50053070, 50054450, 50058375, and 50055408) distant from the main urban area were substantially higher than the historical sampling site at Lago Loíza (station 50055400) but in the same range of those at the other three historical sampling sites (figs. 3*A, B, C, D*, table 2, plate 1). At the last remaining new site, station 50055132, the sanitary quality results are in the same range of those at the historical sampling site at Lago Loíza (figs. 3*A, B, C, D*, appendix 1, plate 1). In general, the major change occurred in the number of sites in the acceptable category, with an increase from 18 sites in the 1997–99 study to 21 sites in the 2014–15 study.

A comparison of the results from the two studies must address two concerns. First, the nine additional stream sampling sites might have increased the resolution of the 2014–15 study, and thus, the resulting stream classifications might be more representative than those of the 1997–99 study. Second, the location of the additional stream sampling sites could affect the comparison of the two studies by shifting the density of the sampling sites among the various subareas of the Municipality of Caguas; for example, three new sampling sites were added along stream reaches not sampled during the 1997–99 study. Considering the low number of new stations in stream reaches not previously sampled, however, and the minimal difference in study area extent between the two investigations, it is reasonable to assume that the comparative analysis between the two studies is valid. Three of the additional stream sampling sites were in urban areas that have a historical record of poor sanitary quality, and no changes in the sanitary quality of stream segments in these particular areas occurred with the increased density of stream sampling sites.

Overall, the spatial distribution of the various classifications of stream sanitary quality during the 2014–15 study is similar to that of the 1997–99 study. Slight to moderate improvements in the sanitary quality of surface waters did occur between the 1997–99 and the 2014–15 assessments (table 1). When using the 1990 standards, the percentage of total stream miles classified as poor decreased by about 15 percent, and the percentage of total stream miles classified as fair decreased by about 40 percent. The percentage of total stream miles classified as acceptable increased by about 24 percent, and the percentage of stream miles classified as good increased by about 15 percent.

The concentration of NO_3 plus NO_2 as N (appendix 1) was below the U.S. Environmental Protection Agency standard for N in drinking water of 10 mg/L (U.S. Environmental Protection Agency, National Primary Drinking Water Regulations (n.d.). The concentration of NO_3 plus NO_2 as N ranged from a minimum of 0.02 mg/L at a tributary of Rio Bairoa at Highway 1 near Caguas (station 50055404) to a maximum of 9.0 mg/L at Quebrada Las Bambúas at Barrio Tomas de Castro (station 50052850) (appendix 1). The $\delta^{15}N\text{-}NO_3$ ranged from a minimum of +8.2 per mil (‰) to a maximum of +14.74 ‰ (table 3). The $\delta^{18}O\text{-}NO_3$ ranged from a minimum of +0.9 ‰ to a maximum of +8.49 ‰ (table 3, fig. 4). The combined use of the $\delta^{15}N\text{-}NO_3$ and $\delta^{18}O\text{-}NO_3$ data indicates that the most likely source of nitrate in the streams of the Municipality of Caguas is animal and human waste (fig. 5). The $\delta^{15}N\text{-}NO_3$ and $\delta^{18}O\text{-}NO_3$ data were collected only during March 2015, which represents the annual dry season. No isotope data were collected during a base-flow period following a storm event that typically occurs during the annual rainy season. Consequently, it could not be determined if potential sources of nitrate depend on the type of base-flow period chosen for sampling.

In addition to leakage from septic tanks, excrement from grazing dairy and beef cattle and poultry farms may also be a major source of fecal contamination to several streams (Gómez-Gómez and others, 2001). The agricultural census of 2012 indicates that the number of beef and dairy cattle and poultry has increased by 55 and 36 percent, respectively, since 2007 (U.S. Department of Agriculture, 2014). The census also registered an increase in the breeding of goats and sheep in the rural areas of Caguas. Results from the 2014–15 study indicate, however, that despite this increase in beef, dairy cattle, goats, and sheep, the overall sanitary quality of surface waters in the rural areas of Caguas has not deteriorated since the 1997–99 study.

Water samples collected at eight sampling sites were analyzed for the presence of 115 HHPPs; detections are shown in appendix 2, and the data are available through the USGS NWIS (U.S. Geological Survey, 2017). Thirty-eight of the 115 HHPPs occurred at or above measurement detection levels. The highest number of HHPPs (32) was detected at the sampling site identified as Tributary of unnamed creek at Highway 156 (station 50055195). Caffeine was the only HHPP detected at all eight sampling sites. Other HHPPs, such as acetaminophen, metformin, acyclovir, and tramadol were detected in at least four of the sampling sites. These data are provided as a baseline and were not used in classifying the sanitary quality of the surface waters in the Municipality of Caguas, because no available criteria are available for these products in surface waters.

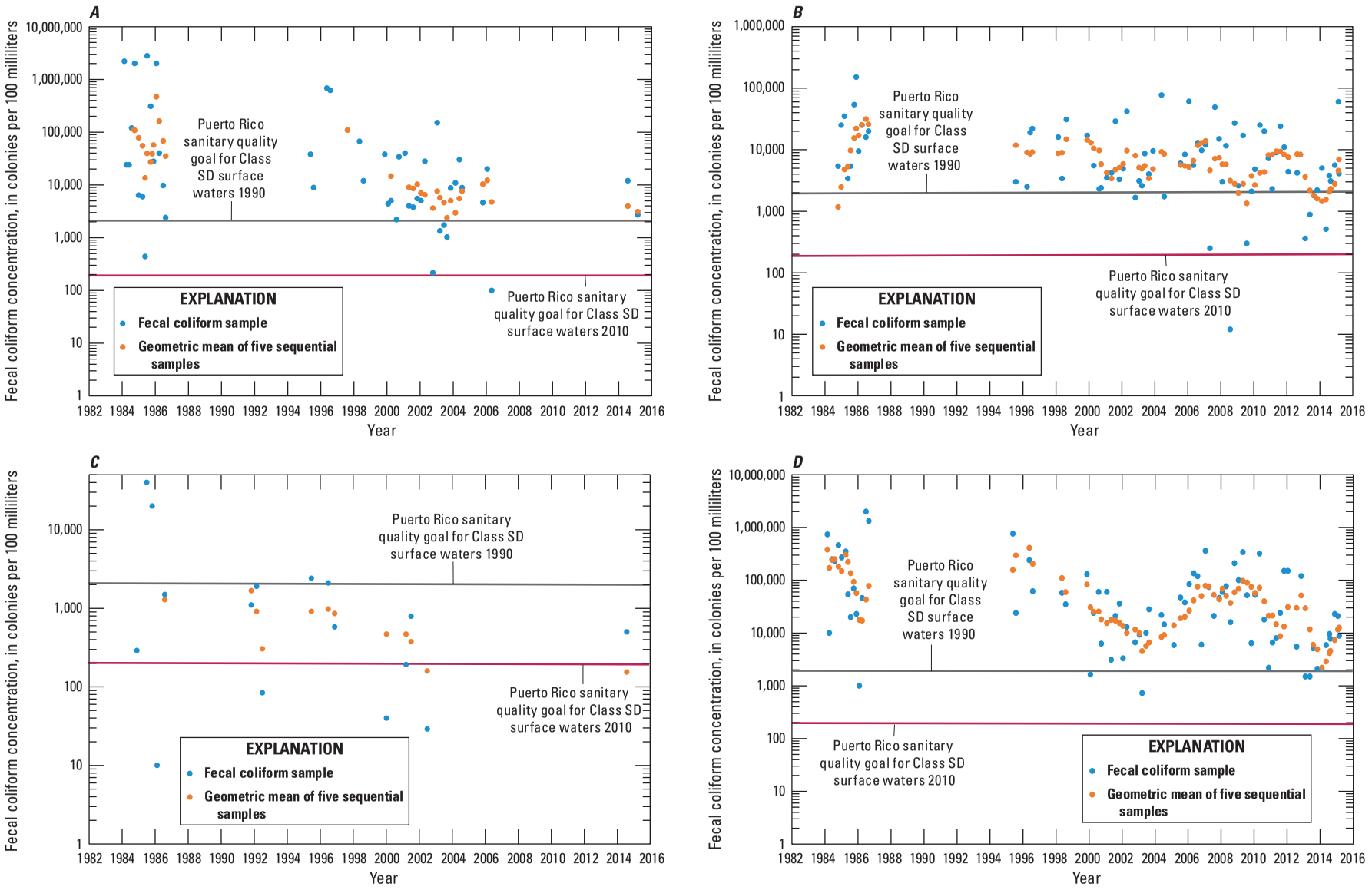


Figure 3. Long-term fecal coliform bacteria concentration and geometric mean from March 1984 to March 2015 at *A*, station 50055400 Rio Bairoa near Caguas, Puerto Rico; *B*, station 50055000 Rio Grande de Loíza at Caguas, Puerto Rico; *C*, station 50057500 Lago Loíza no. 4 near mouth near Caguas, Puerto Rico; and *D*, station 50055250 Rio Caguitas at Highway 30 at Caguas, Puerto Rico.

Table 3. Concentration of nitrate plus nitrite as nitrogen, and nitrogen and oxygen isotopes in nitrate at selected stations in the Municipality of Caguas, Puerto Rico, March 2015.

[USGS, U.S. Geological Survey; N, nitrogen; mg/L, milligrams per liter; ‰, per mil; PR, Puerto Rico; Hwy, highway; nr, near]

USGS station identification number	Station name	Identification number (figs. 4 and 5)	Nitrate plus nitrite as N (mg/L)	Delta nitrogen-15 (‰)	Delta oxygen-18 (‰)
50055000	Rio Grande de Loíza at Caguas, PR	1	0.14	9.77	4.67
50055150	Rio Cañaboncito at Barrio Cañaboncito, PR	2	1.5	13.8	7.44
50055180	Unnamed Creek at Villa del Rey, PR	3	0.68	8.74	5.74
50055190	Unnamed Creek at Hwy 156 nr Caguas, PR	4	0.79	11.1	4.22
50055195	Tributary of Unnamed Creek at Hwy 156 nr Caguas, PR	5	0.40	8.20	0.90
50055250	Rio Caguitas at Hwy 30 at Caguas, PR	6	0.67	10.3	4.27
50055400	Rio Bairoa near Caguas, PR	7	0.99	14.7	8.49
50055410	Rio Bairoa at Mouth, PR	8	4.1	10.7	3.99
50058610	Tributary of Lago Loíza at Hwy 175 San Antonio, PR	9	0.43	12.9	7.52

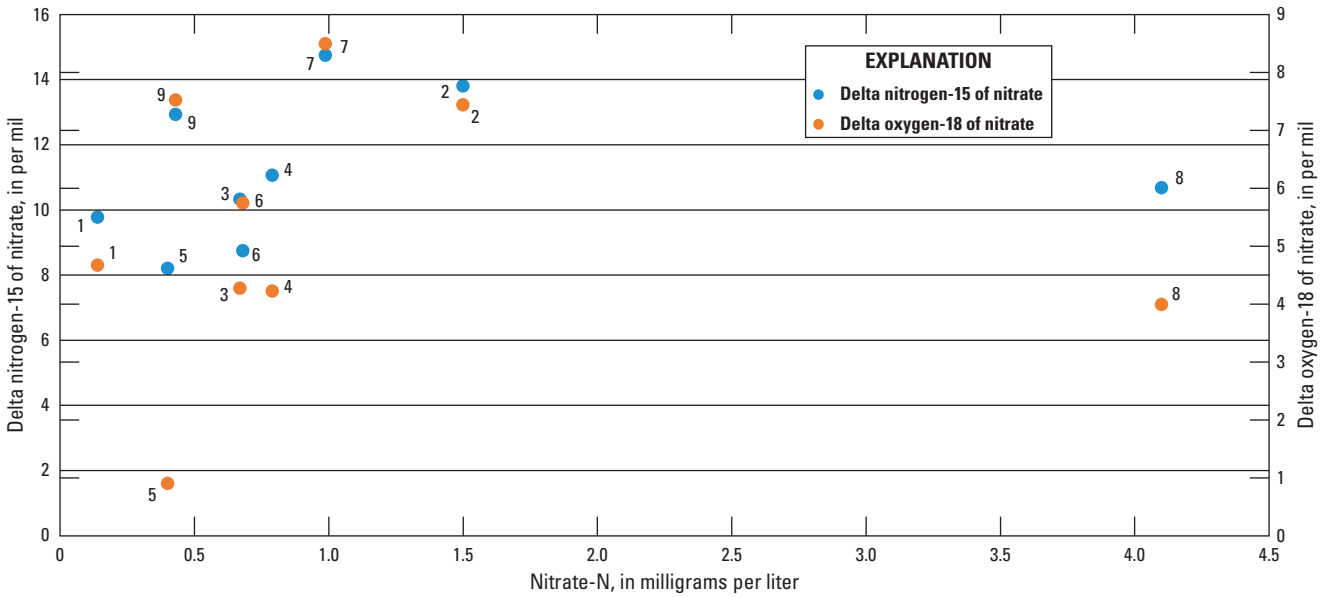


Figure 4. Relation between nitrate-N concentrations and values for delta nitrogen-15 and delta oxygen-18 of nitrate in water samples at selected sites in the Municipality of Caguas, Puerto Rico, 2014–15.

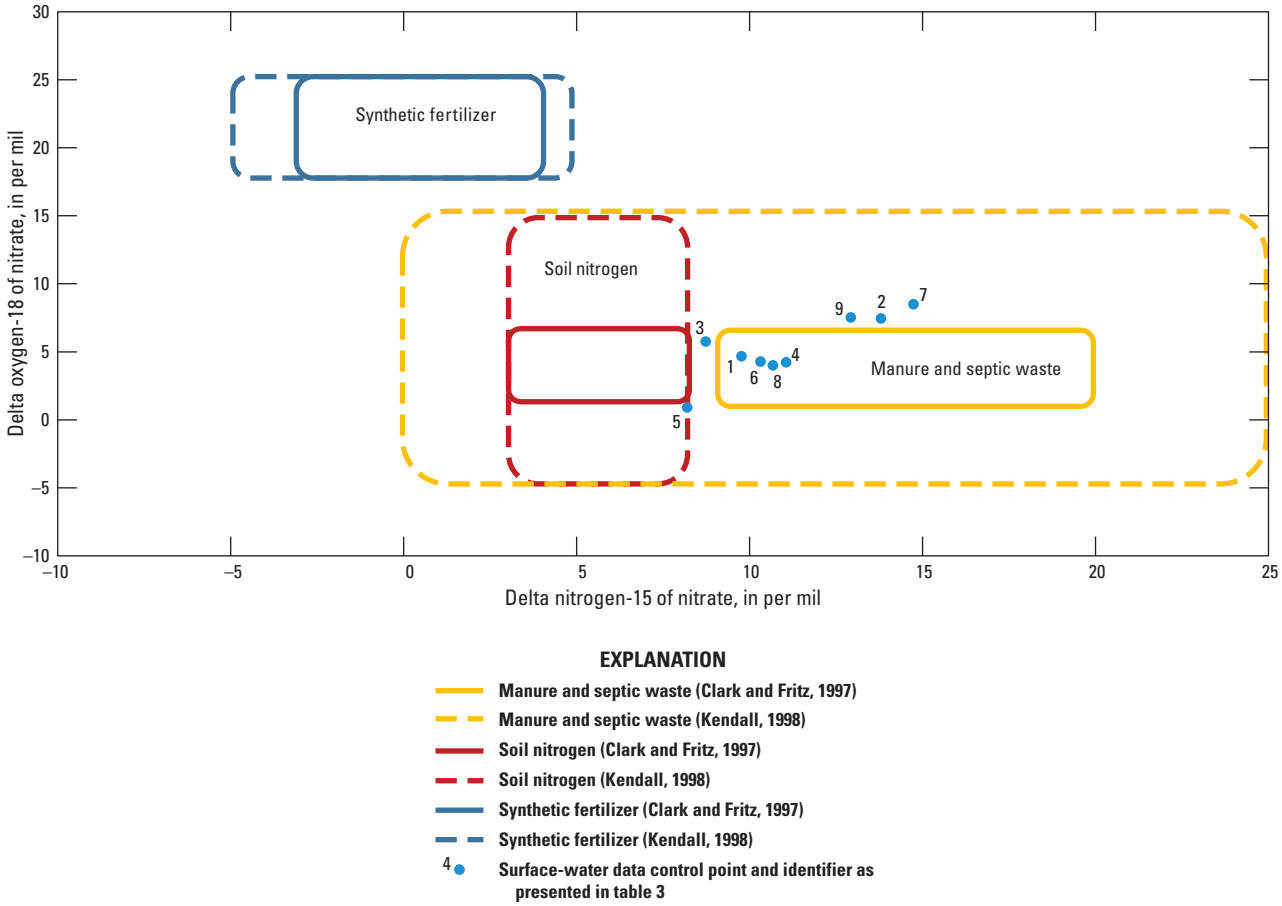


Figure 5. Relation of delta nitrogen-15 and delta oxygen-18 in nitrate and the potential sources of nitrate in water samples at selected sites in the Municipality of Caguas, Puerto Rico, 2014–15.

Summary and Conclusions

A study was conducted by the U.S. Geological Survey, in cooperation with the Municipality of Caguas, Puerto Rico, to determine whether changes in the stream sanitary quality during base-flow conditions have occurred within this municipality since the 1997–99 study by Gómez-Gómez and others (2001). The study consisted of two synoptic surveys made during base-flow conditions in 2014–15; water samples were collected and analyzed for fecal and total coliform bacteria, nitrate (NO_3) plus nitrite (NO_2) as nitrogen, the composition of nitrogen and oxygen isotopes of nitrate, and human health and pharmaceutical products (HHPPs). Sampling for fecal and total coliform bacteria occurred at 50 sampling sites in streams, including 39 sites sampled in 1997–99, and 11 additional stream sites. Two sites sampled in the 1997–99 study were inaccessible and could not be sampled again in 2014–15.

Two samples were collected at each site for fecal and total coliform bacteria and nitrate plus nitrite concentrations. The first sample was collected in August 2014 after base-flow conditions were reached following a major storm and high streamflow event. The second sample was collected in March 2015 during the middle of the dry season when long-term base-flow conditions prevailed. The sampling and analytical methods followed the procedures and protocols established by the USGS. Fecal and total coliform bacteria were collected to determine the sanitary quality of streams as delineated by Gomez-Gomez and others (2001). The composition of nitrogen and oxygen isotopes of nitrate were determined in samples collected from nine sites in March 2015 in order to provide information about the source of nitrate. HHPPs were sampled at eight sites in March 2015. Concentrations of nitrate plus nitrite as nitrogen were not used in the classification of the sanitary quality of surface waters because measured concentrations of nitrogen never exceeded the U.S. Environmental Protection Agency standard of 10 milligrams per liter (mg/L). The concentrations of HHPPs were not used in the classification of the sanitary quality of surface waters in the Municipality of Caguas, because classification criteria for these products in surface waters were not available for 2014–15.

A total of 151 stream miles were classified during the 2014–15 study using the Puerto Rico Environmental Quality Board (PREQB) sanitary quality standards of 1990 and the more rigorous standards adopted by the same agency in 2010. Use of the 1990 standards was necessary to compare the results of the 2014–15 study with those of the 1997–99 study.

The spatial patterns of sanitary quality delineated in 2014–15 using the PREQB standards of 1990 were similar to the patterns reported by Gómez-Gómez and others (2001). The poorest sanitary quality was within the urban area of the Municipality of Caguas, particularly in urban reaches of Río Caguitas, and in rural and suburban areas along stream margins bordered by high-density housing that may have inadequate septic tanks or that discharge domestic wastewater directly into the stream channels. The best sanitary quality was in areas having little or no human development, such as in the wards of San Salvador and Beatriz in the south and southwest parts of Caguas, respectively. The long-term geometric mean concentration of five sequential samples exceeded the 1990 Puerto Rico sanitary quality standards of 2,000 colonies per 100 milliliters for Class SD surface waters at three of four historical sampling sites: Río Bairoa (USGS station 50055400), Río Grande Loíza (USGS station 50055000), and Río Caguitas (USGS station 50055250). The long-term geometric mean concentration of five sequential samples is mostly below the Puerto Rico sanitary quality for Class SD surface waters at the Lago Loíza USGS station (50057500). A slight to moderate improvement in the sanitary quality of surface waters did occur between the 1997–99 and 2014–15 assessments. The percentage of total stream miles classified as poor decreased by about 15 percent, and the percentage of total stream miles classified as fair decreased by about 40 percent. The percentage of total stream miles classified as acceptable increased by about 24 percent, and the percentage of stream miles classified as good increased by about 15 percent

The long-term geometric mean of five sequential samples exceeded the standard of 200 colonies per 100 milliliters implemented in 2010 at all four historical sampling sites. A substantial increase in the number of sampling sites ranked as poor occurred when the classification system followed the stricter PREQB standards of 2010 rather than the more lenient 1990 standards. Only six sampling sites were classified as good when ranked according to the PREQB 2010 standards.

The concentrations of nitrate plus nitrite as nitrogen were below the U.S. Environmental Protection Agency standard for nitrate as nitrogen in drinking water (10 mg/L), and ranged from 0.02 to 9.0 mg/L. The $\delta^{15}N\text{-}NO_3$ ranged from a minimum of +8.2 per mil (‰) to a maximum of +14.74 ‰. The $\delta^{18}O\text{-}NO_3$ ranged from a minimum of +0.9 ‰ to a maximum of +8.49 ‰. The combined results of $\delta^{15}N\text{-}NO_3$ and $\delta^{18}O\text{-}NO_3$ analyses indicate that the nitrate in the streams of the Municipality of Caguas most likely originates from animal and human waste.

Leakage from septic tanks, and excrement from grazing dairy and beef cattle, and from poultry farms, may be the main sources of fecal contamination to several streams in the Municipality of Caguas. An increase in the number of beef and dairy cattle and poultry since 2007 does not appear to have affected the overall sanitary quality of the surface waters within the Municipality of Caguas.

Water samples collected at eight sampling sites were analyzed for the presence of 115 HHPPs. Thirty-eight of the 115 HHPPs occurred at or above measurement detection levels. Caffeine was the only HHPP detected at all eight sampling sites. Other HHPPs, such as acetaminophen, metformin, acyclovir, and tramadol, were detected in four of the sampling sites. The HHPP data are provided as a baseline and were not used in classifying the sanitary quality of the surface waters in the Municipality of Caguas because no criteria are available for classifying these products in surface waters.

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Appendix 1

Table 1–1. Concentrations of fecal and total coliform bacteria, nitrate plus nitrite nitrogen, instantaneous discharge, and sanitary quality classification at surface-water sites within the Municipality of Caguas, 2014–15.

[USGS, U.S. Geological Survey; m/d/y, month, day, year; hhmm, hour, minute; PREQB, Puerto Rico Environmental Quality Board; E, estimated; Stagnant, standing pool of water; NA, not applicable]

USGS station identification number	Site name	Sample date (m/d/y)	Time (hhmm)	Fecal coliform colonies per 100 milliliters	Total coliform colonies per 100 milliliters	Nitrate plus nitrite nitrogen (milligrams per liter)	Instantaneous discharge (cubic feet per second)	Sanitary quality classification PREQB standards of 1990 (Junta de Calidad Ambiental de Puerto Rico, 1990)	Sanitary quality classification PREQB standards of 2010 (Junta de Calidad Ambiental de Puerto Rico, 2010)
50052795	Quebrada Janer at Bo. Tomás de Castro, PR	8/5/2014	1222	854	3,500	0.37	0.18	Acceptable	Poor
50052795	Quebrada Janer at Bo. Tomás de Castro, PR	3/10/2015	0910	1,500	5,900	0.49	0.13		
50052850	Quebrada Las Bambúas at Bo. Tomás de Castro, PR	8/5/2014	1326	2,600	6,500	0.77	0.24	Poor	Poor
50052850	Quebrada Las Bambúas at Bo. Tomás de Castro, PR	3/10/2015	1025	3,900	9,500	9.0	0.17		
50052860	Quebrada Las Bambúas near Caguas, PR	3/10/2015	1115	800	3,200	2.03	0.70	Fair	Poor
50052860	Quebrada Las Bambúas near Caguas, PR	8/6/2014	1445	4700	32000	0.57	2.1		
50052900	Quebrada Las Bambúas at Mouth, PR	8/7/2014	1600	3,700	12,273	0.34	0.57	Fair	Poor
50052900	Quebrada Las Bambúas at Mouth, PR	3/10/2015	1150	1,200	5,900	1.4	0.76		
50052925	Río Turabo at Bo. San Salvador, PR	8/4/2014	1230	100	2,000	0.24	2.7	Good	Good
50052925	Río Turabo at Bo. San Salvador, PR	3/9/2015	1215	91	490	0.26	3.0		
50052935	Quebrada Morena at Bo. San Salvador, PR	8/5/2014	1005	100	700	0.13	1.8	Acceptable	Fair
50052935	Quebrada Morena at Bo. San Salvador, PR	3/9/2015	0940	560	3500	0.14	2.0		
50052950	Quebrada Maracai at Barrio. San Salvador	8/4/2014	1120	520	3,000	0.26	5.5	Acceptable	Poor
50052950	Quebrada Maracai at Barrio. San Salvador	3/9/2015	1155	260	4,200	0.20	4.0		
50052975	Rio Turabo nr Barrio San Salvador	8/4/2014	1415	200	2,500	0.18	9.0	Acceptable	Good
50052975	Rio Turabo nr Barrio San Salvador	3/9/2015	1055	190	580	0.15	6.2		
50053025	Rio Turabo abv Borinquen	8/4/2014	0820	510	5,000	0.26	13	Acceptable	Fair
50053025	Rio Turabo abv Borinquen	3/9/2015	0825	80	340	0.13	8.2		
50053060	Rio Turabo at Hwy 765 at Bo. Borinquen	8/4/2014	0930	600	3,500	0.25	15	Acceptable	Fair
50053060	Rio Turabo at Hwy 765 at Bo. Borinquen	3/9/2015	1045	64	520	0.07	8.5		
50053070	Tributario de Rio Turabo at Hwy 765 at Borinquen	8/4/2014	1130	400	7,500	0.05	0.11	Acceptable	Fair
50053070	Tributario de Rio Turabo at Hwy 765 at Borinquen	3/9/2015	1145	200	2,400	0.04	0.05		

Table 1–1. Concentrations of fecal and total coliform bacteria, nitrate plus nitrite nitrogen, instantaneous discharge, and sanitary quality classification at surface-water sites within the Municipality of Caguas, 2014–15.—Continued

[USGS, U.S. Geological Survey; m/d/y, month, day, year; hhmm, hour, minute; PREQB, Puerto Rico Environmental Quality Board; E, estimated; Stagnant, standing pool of water; NA, not applicable]

USGS station identification number	Site name	Sample date (m/d/y)	Time (hhmm)	Fecal coliform colonies per 100 milliliters	Total coliform colonies per 100 milliliters	Nitrate plus nitrite nitrogen (milligrams per liter)	Instantaneous discharge (cubic feet per second)	Sanitary quality classification PREQB standards of 1990 (Junta de Calidad Ambiental de Puerto Rico, 1990)	Sanitary quality classification PREQB standards of 2010 (Junta de Calidad Ambiental de Puerto Rico, 2010)
50053080	Quebrada Naranjito at Bo. Borinquen	8/4/2014	1040	6,909	13,000	0.24	1.7	Poor	Poor
50053080	Quebrada Naranjito at Bo. Borinquen	3/9/2015	0945	7,700	6,200	0.07	0.42		
50053150	Quebrada Sonadora at Bo. Beatriz, PR	8/4/2014	1105	1,000	3,000	0.15	0.21	Acceptable	Fair
50053150	Quebrada Sonadora at Bo. Beatriz, PR	3/9/2015	1015	18	690	0.16	1.1		
50053200	Quebrada Beatriz at Bo. Beatriz	8/4/2014	0930	400	3,600	0.15	2.5	Acceptable	Poor
50053200	Quebrada Beatriz at Bo. Beatriz	3/9/2015	1220	270	1,000	0.08	2.2		
50053250	Tributario de Qda Beatriz at Hwy 765 at Borinquen	8/4/2014	1215	1,400	4,200	0.55	0.29	Acceptable	Poor
50053250	Tributario de Qda Beatriz at Hwy 765 at Borinquen	3/9/2015	0905	450	3,500	0.38	0.18		
50053925	Qda de Las Quebradillas at Divisoria at Bo Beatriz	8/5/2014	0845	130	1,818	1.1	2.0	Good	Good
50053925	Qda de Las Quebradillas at Divisoria at Bo Beatriz	3/10/2015	0800	120	2,700	1.5	0.84		
50053950	Quebrada de Las Quebradillas at Bo. Beatriz	8/5/2014	1020	127	2,000	0.91	3.3	Good	Good
50053950	Quebrada de Las Quebradillas at Bo. Beatriz	3/10/2015	0915	40	600	1.2	2.4		
50053975	Qda de Las Quebradillas abv Dam at Bo. Turabo, PR	8/5/2014	1145	340	3,700	0.26	E 0.01	Acceptable	Poor
50053975	Qda de Las Quebradillas abv Dam at Bo. Turabo, PR	3/10/2015	1030	1,000	5,500	0.06	Stagnant		
50054020	Quebrada de Las Quebradillas at Highway 1	8/5/2014	0725	1,263	3,400	0.52	1.8	Fair	Poor
50054020	Quebrada de Las Quebradillas at Highway 1	3/10/2015	1055	61,000	270,000	0.74	0.27		
50054050	Qda de Las Quebradillas nr Mouth at Bo. Turabo	8/5/2014	0850	510	2,100	0.39	2.2	Acceptable	Poor
50054050	Qda de Las Quebradillas nr Mouth at Bo. Turabo, PR	3/10/2015	0815	600	9,000	0.48	0.79		

Table 1–1. Concentrations of fecal and total coliform bacteria, nitrate plus nitrite nitrogen, instantaneous discharge, and sanitary quality classification at surface-water sites within the Municipality of Caguas, 2014–15.—Continued

[USGS, U.S. Geological Survey; m/d/y, month, day, year; hhmm, hour, minute; PREQB, Puerto Rico Environmental Quality Board; E, estimated; Stagnant, standing pool of water; NA, not applicable]

USGS station identification number	Site name	Sample date (m/d/y)	Time (hhmm)	Fecal coliform colonies per 100 milliliters	Total coliform colonies per 100 milliliters	Nitrate plus nitrite nitrogen (milligrams per liter)	Instantaneous discharge (cubic feet per second)	Sanitary quality classification PREQB standards of 1990 (Junta de Calidad Ambiental de Puerto Rico, 1990)	Sanitary quality classification PREQB standards of 2010 (Junta de Calidad Ambiental de Puerto Rico, 2010)
50054100	Rio Turabo at Bo. Turabo, PR	8/5/2014	0955	260	2,100	0.27	18	Acceptable	Fair
50054100	Rio Turabo at Bo. Turabo, PR	3/10/2015	0930	30	480	0.06	10		
50054300	Rio Turabo at Villa del Rey nr Caguas, PR	8/5/2014	1215	73	700	0.26	16	Acceptable	Fair
50054300	Rio Turabo at Villa del Rey nr Caguas, PR	3/10/2015	1105	700	4,200	0.07	14		
50054450	Tributary of Rio Turabo nr Tomás de Castro, PR	8/5/2014	1345	1,500	6,900	0.40	0.35	Acceptable	Fair
50054450	Tributary of Rio Turabo nr Tomás de Castro, PR	3/11/2015	0820	18	900	0.26	0.23		
50054500	Rio Turabo at Caguas, PR	8/8/2014	0835	727	2,500	0.21	15	Acceptable	Poor
50054500	Rio Turabo at Caguas, PR	3/13/2015	0830	370	2,400	0.11	12		
50055000	Rio Grande de Loiza at Caguas, PR	8/7/2014	0950	3,800	24,000	0.34	149	Poor	Poor
50055000	Rio Grande de Loiza at Caguas, PR	3/12/2015	0745	4,100	27,000	0.14	52		
50055097	Quebrada Sanjelo at Hwy 777, PR	8/6/2014	1120	649	3,800	0.59	0.73	Fair	Poor
50055097	Quebrada SanJelo at Hwy 777, PR	3/11/2015	1240	4,900	26,000	0.97	0.74		
50055120	Rio Caguitas at Hwy 156 nr Caguas, PR	8/6/2014	0945	450	5,000	0.50	3.3	Acceptable	Poor
50055120	Rio Caguitas at Hwy 156 nr Caguas, PR	3/11/2015	0945	290	2,000	0.92	3.5		
50055130	Quebrada Algarrobo at Bo. Canabon, PR	8/6/2014	1030	4,500	20,000	0.61	0.01	Fair	Fair
50055130	Quebrada Algarrobo at Bo. Canabon, PR	3/11/2015	1025	110	22,000	0.16	0.01		
50055132	Tributary of Quebrada Algarrobo at Mouth, PR	8/6/2014	0850	180	220	0.36	Stagnant	Good	Good
50055132	Tributary of Quebrada Algarrobo at Mouth, PR	3/11/2015	0835	160	530	0.29	E 0.06		
50055135	Quebrada Algarrobo at Mouth at Bo. Canabon, PR	8/6/2014	0805	200	3,000	0.15	0.09	Acceptable	Good
50055135	Quebrada Algarrobo at Mouth at Bo. Canabon, PR	3/11/2015	0750	82	6,500	0.08	0.17		
50055150	Rio Canaboncito at Bo. Canaboncito, PR	8/6/2014	1120	6,500	26,000	0.95	2.9	Fair	Poor
50055150	Rio Canaboncito at Bo. Canaboncito, PR	3/11/2015	1110	250	2,800	1.5	0.78		

Table 1–1. Concentrations of fecal and total coliform bacteria, nitrate plus nitrite nitrogen, instantaneous discharge, and sanitary quality classification at surface-water sites within the Municipality of Caguas, 2014–15.—Continued

[USGS, U.S. Geological Survey; m/d/y, month, day, year; hhmm, hour, minute; PREQB, Puerto Rico Environmental Quality Board; E, estimated; Stagnant, standing pool of water; NA, not applicable]

USGS station identification number	Site name	Sample date (m/d/y)	Time (hhmm)	Fecal coliform colonies per 100 milliliters	Total coliform colonies per 100 milliliters	Nitrate plus nitrite nitrogen (milligrams per liter)	Instantaneous discharge (cubic feet per second)	Sanitary quality classification PREQB standards of 1990 (Junta de Calidad Ambiental de Puerto Rico, 1990)	Sanitary quality classification PREQB standards of 2010 (Junta de Calidad Ambiental de Puerto Rico, 2010)
50055160	Rio Canaboncito nr Mouth at Bo. Canaboncito, PR	8/6/2014	0920	3,000	7,800	0.56	2.8	Fair	Fair
50055160	Rio Canaboncito nr Mouth at Bo. Canaboncito, PR	3/11/2015	0940	80	1,100	0.81	0.91		
50055170	Rio Caguitas nr Caguas, PR	8/6/2014	1410	2,400	5,000	0.21	8.4	Poor	Poor
50055170	Rio Caguitas nr Caguas, PR	3/13/2015	0900	80,000	84,000	0.40	6.3		
50055180	Unnamed Creek at Villa del Rey, PR	8/7/2014	1305	6,000	28,000	1.1	0.34	Poor	Poor
50055180	Unnamed Creek at Villa del Rey, PR	3/13/2015	1000	40,000	250,000	0.68	1.8		
50055190	Unnamed Creek at Highway 156 nr Caguas, PR	8/7/2014	1045	20,000	85,454	0.71	0.84	Poor	Poor
50055190	Unnamed Creek at Highway 156 nr Caguas, PR	3/12/2015	1055	13,000	100,000	0.79	0.82		
50055195	Tributary of Unnamed Creek at Hwy 156 near Caguas, PR	8/7/2014	0915	760,000	2,140,000	0.06	0.29	Poor	Poor
50055195	Tributary of Unnamed Creek at Hwy 156 near Caguas, PR	3/12/2015	0950	63,000	270,000	0.40	0.41		
50055250	Rio Caguitas at Hwy 30 at Caguas, PR	8/7/2014	0815	9,549	500,000	0.63	10	Poor	Poor
50055250	Rio Caguitas at Hwy 30 at Caguas, PR	3/12/2015	0845	8,900	44,000	0.67	17		
50055330	Rio Bairoa at Bo. Bairoa nr Caguas, PR	8/7/2014	0955	660	3,400	1.5	2.2	Fair	Poor
50055330	Rio Bairoa at Bo. Bairoa nr Caguas, PR	3/12/2015	0945	3,100	30,000	1.3	3.2		
50055335	Rio Bairoa below Las Carolinas, PR	8/7/2014	0905	1,000	8,200	1.1	2.3	Acceptable	Poor
50055335	Rio Bairoa below Las Carolinas, PR	3/12/2015	0855	1,600	27,000	1.3	4.8		
50055400	Rio Bairoa nr Caguas, PR	8/7/2014	1220	12,000	50,000	0.84	2.8	Poor	Poor
50055400	Rio Bairoa nr Caguas, PR	3/13/2015	0800	2,700	9,200	0.99	3.8		
50055404	Tributario de Rio Bairoa at Hwy 1 nr Caguas, PR	8/7/2014	1125	7,182	25,000	0.04	E 0.01	Fair	Poor
50055404	Tributario de Rio Bairoa at Hwy 1 nr Caguas, PR	3/11/2015	1030	400	2,200	0.02	Stagnant		

Table 1–1. Concentrations of fecal and total coliform bacteria, nitrate plus nitrite nitrogen, instantaneous discharge, and sanitary quality classification at surface-water sites within the Municipality of Caguas, 2014–15.—Continued

[USGS, U.S. Geological Survey; m/d/y, month, day, year; hhmm, hour, minute; PREQB, Puerto Rico Environmental Quality Board; E, estimated; Stagnant, standing pool of water; NA, not applicable]

USGS station identification number	Site name	Sample date (m/d/y)	Time (hhmm)	Fecal coliform colonies per 100 milliliters	Total coliform colonies per 100 milliliters	Nitrate plus nitrite nitrogen (milligrams per liter)	Instantaneous discharge (cubic feet per second)	Sanitary quality classification PREQB standards of 1990 (Junta de Calidad Ambiental de Puerto Rico, 1990)	Sanitary quality classification PREQB standards of 2010 (Junta de Calidad Ambiental de Puerto Rico, 2010)
50055408	Tributary of Rio Bairoa at Hwy 796 nr Caguas, PR	8/6/2014	1110	1,658	20,000	0.59	0.7	Acceptable	Poor
50055408	Tributary of Rio Bairoa at Hwy 796 nr Caguas, PR	3/11/2015	0945	350	3,600	0.90	0.38		
50055410	Rio Bairoa at Mouth, PR	8/7/2014	0715	3,600	32,000	3.4	19	Poor	Poor
50055410	Rio Bairoa at Mouth, PR	3/12/2015	1015	2,900	19,000	4.1	33		
50057500	LAGO Loiza No. 4 nr Mouth nr Caguas, PR	8/8/2014	1035	500	4,500	0.94	NA	Acceptable	Poor
50057500	LAGO Loiza No. 4 nr Mouth nr Caguas, PR	3/12/2015	1500	240	890	0.99	NA		
50057800	Rio Canas at Bo. Jagueyes nr Rio Canas, PR	8/8/2014	0810	613	4,545	0.25	0.55	Acceptable	Fair
50057800	Rio Canas at Bo. Jagueyes nr Rio Canas, PR	3/13/2015	0750	36	2,800	0.60	0.67		
50058010	Rio Canas at Hwy 1 at Bo. Rio Canas, PR	8/14/2014	0855	820	4,800	0.41	1.3	Acceptable	Poor
50058010	Rio Canas at Hwy 1 at Bo. Rio Canas, PR	3/12/2015	1220	220	4,000	0.67	2.7		
50058300	Quebrada Arena nr Caguas, PR	8/8/2014	0655	1,818	4,500	0.65	1.7	Acceptable	Fair
50058300	Quebrada Arena nr Caguas, PR	3/13/2015	0845	140	2,000	0.73	3.2		
50058375	Tributario de Rio Canas at Hwy 798 at Bo Rio Canas	8/8/2014	1040	2,800	36,000	1.09	0.67	Poor	Poor
50058375	Tributario de Rio Canas at Hwy 798 at Bo Rio Canas	3/12/2015	1145	4,100	14,000	1.3	0.48		
50058395	Tributary of Trib of Rio Canas at Hwy 798, PR	8/8/2014	1015	4,800	25,000	1.1	0.67	Fair	Poor
50058395	Tributary of Trib of Rio Canas at Hwy 798, PR	3/12/2015	1115	1,400	9,100	0.85	0.8		
50058610	Tributario de Lago Loiza at Hwy 175 at San Antonio	8/8/2014	1249	20,000	75,000	0.56	0.11	Fair	Poor
50058610	Tributario de Lago Loiza at Hwy 175 at San Antonio	3/12/2015	1345	1,700	6,500	0.43	0.28		

Appendix 2

Table 2–1. Concentrations of human health and pharmaceutical products at selected sampling stations in the Municipality of Caguas, Puerto Rico, March 2015.

[Station locations are shown in figure 2. m/dd/yyyy, month, day, year; ng/L, nanograms per liter; E, estimated]

Human health and pharmaceutical products	Date of sampling (m/dd/yyyy)	Concentration (ng/L)
Rio Grande de Loíza at Caguas (50055000)		
Acetaminophen	3/12/2015	92.8
Caffeine	3/12/2015	122
Carbamazepine	3/12/2015	0.97
Cotinine	3/12/2015	7.23
Lidocaine	3/12/2015	7.90
Nicotine	3/12/2015	68.9
Metformin	3/12/2015	287
Tributary of unnamed creek at Hwy 156 (50055195)		
10-Hydroxy-amitriptyline	3/12/2015	6.07
Abacavir	3/12/2015	0.60
Acetaminophen	3/12/2015	5,650
Acyclovir	3/12/2015	25.6
Albuterol	3/12/2015	3.64
Atenolol	3/12/2015	E346
Bupropion	3/12/2015	9.15
Caffeine	3/12/2015	2,210
Citalopram	3/12/2015	58.7
Codeine	3/12/2015	5.65
Cotinine	3/12/2015	162
Desvenlafaxine	3/12/2015	E28.0
Dextromethorphan	3/12/2015	5.63
Diltiazem	3/12/2015	22.2
Dimethylxanthine	3/12/2015	1,070
Diphenhydramine	3/12/2015	66.5
Fexofenadine	3/12/2015	126
Fluconazole	3/12/2015	7.94
Lamivudine	3/12/2015	E81.4
Lidocaine	3/12/2015	162
Metformin	3/12/2015	3,180
Methylbenzotriazole	3/12/2015	348
Morphine	3/12/2015	E24.9
Nicotine	3/12/2015	397
Pentoxifylline	3/12/2015	26.8
Pseudoephedrine + Ephedrine	3/12/2015	131
Sitagliptin	3/12/2015	111

Table 2–1. Concentrations of human health and pharmaceutical products at selected sampling stations in the Municipality of Caguas, Puerto Rico, March 2015.—Continued

[Station locations are shown in figure 2. m/dd/yyyy, month, day, year; ng/L, nanograms per liter; E, estimated]

Human health and pharmaceutical products	Date of sampling (m/dd/yyyy)	Concentration (ng/L)
Temazepam	3/12/2015	390
Tramadol	3/12/2015	248
Trimethoprim	3/12/2015	E77.5
Venlafaxine	3/12/2015	12.3
Verapamil	3/12/2015	2.32
Río Caguitas at Hwy 30 at Caguas (50055250)		
Acetaminophen	3/12/2015	108
Acyclovir	3/12/2015	22.3
Caffeine	3/12/2015	170
Cotinine	3/12/2015	19.7
Fexofenadine	3/12/2015	7.96
Fluconazole	3/12/2015	4.33
Lidocaine	3/12/2015	21.6
Metformin	3/12/2015	751
Methylbenzotriazole	3/12/2015	1,022
Nicotine	3/12/2015	108
Piperonyl butoxide	3/12/2015	4.86
Pseudoephedrine + Ephedrine	3/12/2015	9.94
Temazepam	3/12/2015	31.6
Río Bairoa at mouth (50055410)		
Acetaminophen	3/12/2015	17.2
Acyclovir	3/12/2015	226
Albuterol	3/12/2015	12.7
Atenolol	3/12/2015	E127
Bupropion	3/12/2015	71.4
Carbamazepine	3/12/2015	88.2
Caffeine	3/12/2015	138
Carisoprodol	3/12/2015	44.7
Chlorpheniramine	3/12/2015	E4.48
Citalopram	3/12/2015	25.7
Codeine	3/12/2015	6.84
Cotinine	3/12/2015	5.89
Dextromethorphan	3/12/2015	168
Diltiazem	3/12/2015	52.0
Diphenhydramine	3/12/2015	38.6
Fexofenadine	3/12/2015	309

Table 2–1. Concentrations of human health and pharmaceutical products at selected sampling stations in the Municipality of Caguas, Puerto Rico, March 2015.—Continued

[Station locations are shown in figure 2. m/dd/yyyy, month, day, year; ng/L, nanograms per liter; E, estimated]

Human health and pharmaceutical products	Date of sampling (m/dd/yyyy)	Concentration (ng/L)
Fluconazole	3/12/2015	165
Lidocaine	3/12/2015	355
Metformin	3/12/2015	240
Methocarbamol	3/12/2015	79.6
Nicotine	3/12/2015	86.1
Sitagliptin	3/12/2015	484
Sulfamethoxazole	3/12/2015	308
Temazepam	3/12/2015	279
Tramadol	3/12/2015	865
Triamterene	3/12/2015	9.99
Venlafaxine	3/12/2015	107
Verapamil	3/12/2015	76.8
Lago Loíza No. 4 near mouth near Caguas (50057500)		
Acetaminophen	3/12/2015	33.0
Acyclovir	3/12/2015	46.3
Albuterol	3/12/2015	3.72
Bupropion	3/12/2015	15.1
Caffeine	3/12/2015	110
Carbamazepine	3/12/2015	25.3
Cotinine	3/12/2015	9.36
Dextromethorphan	3/12/2015	42.8
Diphenhydramine	3/12/2015	5.63
Fluconazole	3/12/2015	55.4
Fluoxetine	3/12/2015	26.9
Lidocaine	3/12/2015	109
Metformin	3/12/2015	386
Methadone	3/12/2015	2.64
Methocarbamol	3/12/2015	22.1
Methylbenzotriazole	3/12/2015	442
Nicotine	3/12/2015	91.3
Oxycodone	3/12/2015	2.80
Pentoxifylline	3/12/2015	4.90
Piperonyl butoxide	3/12/2015	0.22
Pseudoephedrine + Ephedrine	3/12/2015	4.05
Sitagliptin	3/12/2015	118
Sulfamethoxazole	3/12/2015	92.5
Temazepam	3/12/2015	98.7
Tramadol	3/12/2015	203
Triamterene	3/12/2015	2.66
Venlafaxine	3/12/2015	27.2
Río Cañas at Hwy 1 at Barrio Río Cañas, Caguas (50058010)		
Acetaminophen	3/30/2015	7.78
Caffeine	3/30/2015	58.8
Metformin	3/30/2015	62.8
Tributario de Río Cañas at Hwy 798 at Barrio Río Cañas (50058375)		
Caffeine	3/12/2015	904
Cotinine	3/12/2015	11.0
Fluconazole	3/12/2015	9.05
Lidocaine	3/12/2015	306
Metformin	3/12/2015	359
Nicotine	3/12/2015	126
Pentoxifylline	3/12/2015	2.22
Sulfamethoxazole	3/12/2015	45.5
Temazepam	3/12/2015	34.9
Tramadol	3/12/2015	18.1
Tributario de Lago Loíza at Hwy 175 at San Antonio (50058610)		
Caffeine	3/30/2015	16.8
Cotinine	3/30/2015	12.1
Lidocaine	3/30/2015	17.2
Morphine	3/30/2015	E18.9
Pentoxifylline	3/30/2015	87.0
Phenazopyridine	3/30/2015	E3.69

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