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PREPARED IN COOPERATION WITH THE  
MUNICIPIO AUTÓNOMO DE MAYAGÜEZ, PUERTO RICO, OFFICE OF THE MAYOR

# Surface-Water, Water-Quality, and Ground-Water Assessment of the Municipio of Mayagüez, Puerto Rico, 1999-2002

WATER-RESOURCES INVESTIGATIONS REPORT 03-4317



**Cover photograph**

View from Cerro Las Mesas looking northwest. In the foreground is a portion of the Mayagüez urban area that includes, towards the right, the campus of the University of Puerto Rico at Mayagüez and the Palacio de los Deportes Coliseum. In the background toward the left, is the dock area of the Bahía de Mayagüez adjoining Punta Algarrobo. Also in the background toward the right, is the Bahía de Añasco bordered in the north by the Punta Higuero.

Photograph taken by Francisco Maldonado on February 24, 2004.

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By Jesús Rodríguez-Martínez, Luis Santiago-Rivera, Senén Guzmán-Ríos, Fernando Gómez-Gómez, and Mario L. Oliveras-Feliciano

Chapter A

## **Surface-Water Resources Assessment of the Municipio of Mayagüez, Puerto Rico, 1999-2002**

By Luis Santiago-Rivera and Fernando Gómez-Gómez

Chapter B

## **Sanitary Quality of Surface Water During Base-Flow Conditions in the Municipio of Mayagüez, Puerto Rico, 2000-01**

By Senén Guzmán-Ríos, Fernando Gómez-Gómez, and Mario L. Oliveras-Feliciano

Chapter C

## **Hydrogeologic Terranes and Ground-Water Resources in the Municipio of Mayagüez, Puerto Rico, 1999-2002**

By Jesús Rodríguez-Martínez

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## Conversion Factors, Datum, Water-Quality Units, Acronyms, and Translations

Multiply	By	To obtain
<b>Length</b>		
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
<b>Area</b>		
acre	4,047	square meter (m <sup>2</sup> )
square mile (mi <sup>2</sup> )	2.590	square kilometer (km <sup>2</sup> )
<b>Volume</b>		
gallon (gal)	3.785	liter (L)
acre-foot (acre-ft)	1,233	cubic meter (m <sup>3</sup> )
<b>Flow rate</b>		
foot per day (ft/d)	0.3048	meter per day (m/d)
cubic foot per second (ft <sup>3</sup> /s)	0.02832	cubic meter per second (m <sup>3</sup> /s)
cubic foot per second per square mile [(ft <sup>3</sup> /s)/mi <sup>2</sup> ]	0.01093	cubic meter per second per square kilometer [(m <sup>3</sup> /s)/km <sup>2</sup> ]
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m <sup>3</sup> /d)
gallon per day per square mile [(gal/d)mi <sup>2</sup> ]	0.001461	cubic meter per day per square kilometer [(m <sup>3</sup> /d)/km <sup>2</sup> ]
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m <sup>3</sup> /s)
inch per hour (in/h)	0.0254	meter per hour (m/h)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
<b>Transmissivity*</b>		
foot squared per day (ft <sup>2</sup> /d)	0.09290	meter squared per day (m <sup>2</sup> /d)

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

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

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929) - a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called "Sea Level Datum of 1929".

Horizontal Datum - Puerto Rico Datum, 1940 Adjustment

\*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft<sup>3</sup>/d)/ft<sup>2</sup>]ft. In this report, the mathematically reduced form, foot squared per day (ft<sup>2</sup>/d), is used for convenience.

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

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



**Abbreviated water-quality units used in this report:**

µg/L	microgram per liter
µS/cm	microsiemen per centimeter
mL	milliliter

**Acronyms used in this report:**

CAPR	Compañía de Aguas de Puerto Rico
FEMA	Federal Emergency Management Agency
PR	Puerto Rico
PRASA	Puerto Rico Aqueduct and Sewer Authority
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

**Translations:**

Commonly used Spanish terms and their equivalent in English

<i>Spanish</i>	<i>English</i>
barrio	ward
caño	usually equivalent to river, channel, or drainage ditch
lago	lake
municipio	usually equivalent to county
pozo	well
quebrada	stream or creek
río	river



# Surface-Water, Water-Quality, and Ground-Water Assessment of the Municipio of Mayagüez, Puerto Rico, 1999-2002

By Jesús Rodríguez-Martínez, Luis Santiago-Rivera, Senén Guzmán-Ríos, Fernando Gómez-Gómez, and Mario L. Oliveras-Feliciano

## Abstract

The surface-water assessment portion of this study focused on analysis of low-flow characteristics in local streams and rivers, because the supply of safe drinking water was a critical issue during recent dry periods. Low-flow characteristics were evaluated at one continuous-record gaging station based on graphical curve-fitting techniques and log-Pearson Type III frequency curves. Estimates of low-flow characteristics for 20 partial-record stations were generated using graphical-correlation techniques. Flow-duration characteristics for the continuous- and partial-record stations were estimated using the relation curves developed for the low-flow study. Stream low-flow statistics document the general hydrology under current land use, water-use, and climatic conditions.

A survey of streams and rivers utilized 37 sampling stations to evaluate the sanitary quality of about 165 miles of stream channels. River and stream samples for fecal coliform and fecal streptococcus analyses were collected on two occasions at base-flow conditions. Bacteriological analyses indicate that a significant portion of the stream reaches within the municipio of Mayagüez may have fecal coliform bacteria concentrations above the water-quality goal (standard) established by the Puerto Rico Environmental Quality Board (Junta de Calidad Ambiental de Puerto Rico) for inland surface waters. Sources of fecal contamination may include: illegal discharge of sewage to storm-water drains, malfunctioning sanitary sewer ejectors, clogged and leaking sewage pipes, septic tank leakage, unfenced livestock, and runoff from livestock pens. Long-term fecal coliform data from five sampling stations located within or in the vicinity of the municipio of Mayagüez have been in compliance with the water-quality goal for fecal coliform concentration established in July 1990.

Geologic, topographic, soil, hydrogeologic, and streamflow data were compiled into a database and used to divide the municipio of Mayagüez into five hydrogeologic terranes. This integrated database then was used to evaluate the

ground-water potential of each hydrogeologic terrane. Lineament-trace analysis was used to help assess the ground-water development potential in the hydrogeologic terranes containing igneous rocks. Analyses suggest that areas with slopes greater than 15 degrees have relatively low ground-water development potential. The presence of fractures, independent of the topographic slope, may locally enhance the water-bearing properties in the hydrogeologic terranes containing igneous rocks. The results of this study indicate that induced streamflow generally is needed to sustain low to moderate ground-water withdrawal rates in the five hydrogeologic terranes. The ground-water flow systems in the hydrogeologic terranes are only able to sustain small withdrawal rates that rarely exceed 50 gallons per minute. Areas with a high density of fractures, as could be the case at the intersection of lineament traces in the upper parts of the Río Cañas and Río Yagüez watersheds, are worthy of exploratory drilling for ground-water development.

## Sumario

El U.S. Geological Survey, en cooperación con la oficina del Alcalde del Municipio Autónomo de Mayagüez, llevó a cabo un estudio de los recursos de agua superficial y subterránea en dicho municipio. Los planificadores municipales necesitaban un documento integrador que le permitiera la selección de alternativas para satisfacer las demandas presentes y futuras de agua, así como la identificación de fuentes adicionales de abasto de agua. Los resultados principales de este estudio fueron entrados a un sistema de información geográfica y se muestran en dos mapas a escala de 1:30,000 para facilitar la interpretación y el uso de la información diversa sobre los recursos de agua.

La parte de este estudio correspondiente al agua superficial se concentró en el análisis de los flujos mínimos en los ríos y arroyos del municipio, ya que el abasto de agua potable fue un asunto crítico durante periodos recientes de sequía. Se evaluaron las características de flujos mínimos en una estación





#### **4 Surface-Water, Water-Quality, and Ground-Water Assessment of the Municipio of Mayagüez, Puerto Rico, 1999-2002**

Several products are included in this report. Thematic maps with explanatory text were developed to delineate the hydrologic and stream sanitary (bacteriological) conditions, and to define the water-bearing properties of major rock units. A description of the methods and techniques used in the analyses and interpretation are given in separate chapters of this report. Chapter A documents the results of the surface-water assessment, Chapter B documents stream bacteriological conditions, and Chapter C documents ground-water availability.

### **Previous Studies**

Prior to this study, the water resources of the municipio of Mayagüez had not been formally assessed. Only the coastal northwestern portion of the municipio had been evaluated as part of a study by Díaz and Jordan (1987), which focused on the water resources of the lower reaches of the Río Grande de Añasco alluvial valley. Before conducting the present study, the only continuous hydrologic data were collected at a water-quality station (station number 50138800) on the Río Yagüez near the town of Mayagüez. The data collected from this station are published annually by the USGS (Díaz and others, 1995, 1996, 1997, 1998, 1999, 2000, and 2001).

# Chapter A: Surface-Water Resources Assessment of the Municipio of Mayagüez, Puerto Rico, 1999-2002

By Luis Santiago-Rivera and Fernando Gómez-Gómez

## Purpose and Scope

The U.S. Geological Survey (USGS), in cooperation with the municipio of Mayagüez, conducted an investigation of the surface- and ground-water resources from October 1, 1999, to September 30, 2002, in the area primarily within the geographic limits of the municipio of Mayagüez (plate 1). A major component of the study was an assessment of the magnitude and frequency of stream low-flow and flow-duration characteristics, which are important for storage-facility design, waste-load allocation, water-supply planning, recreation, and wildlife conservation. In addition, the current assessment provides reference conditions to assess future changes in flow magnitude, duration, and frequency.

The low-flow and flow-duration monitoring network in Mayagüez included 1 long-term continuous-record (index) gaging station and 20 partial-record stations (tables 1 and 2, respectively, at end of chapter). The continuous-record gaging station (50136400) is located on Río Rosario, a second-order tributary of Río Guanajibo (plate 1). The 20 partial-record stations are distributed among a number of streams within the geographic limits of the municipio of Mayagüez (plate 1). Streamflow was measured concurrently eight times at the index station and partial-record stations at selected base-flow recessions during a 2-year period, from March 2000 to March 2002. These data were used to obtain low-flow and flow-duration estimates. The 7-day, 10-year ( $7Q_{10}$ ) and 7-day, 2-year ( $7Q_2$ ) low-flow frequency characteristics were computed for the continuous-record gaging station and estimated for the partial-record stations. Flow-duration characteristics for 99-, 95-, and 90-percent probability of exceedance also were computed for the continuous-record gaging station and estimated for the 20 partial-record stations.

Pertinent information regarding surface-water hydrology within the municipio of Mayagüez is presented on a thematic map (plate 1). The map displays the following information:

- streamflow data-collection sites;
- drainage-basin boundaries for the streamflow sites in which the low flows were determined;
- potential public-water supply reservoir sites (Black and Veatch, 1976);
- flood-prone areas as delineated by the Federal Emergency Management Agency (1996);
- water filtration plants; and
- active and closed public waste-water treatment facilities.

## Methodology

A series of eight discharge measurements were taken concurrently at 1 continuous- and 20 partial-record stream-gaging stations, to provide the data for a systematic low-flow and flow-duration analysis. A number of techniques were applied to compute low-flow characteristics at continuous- and partial-record stations. Analyses of low-flow characteristics for the continuous-record gaging station (index station) were based on frequency analyses of the annual minimum 7-day low flows (table 1). Using the streamflow data generated during this study, the partial-record station base-flow measurements were related to concurrent base-flow discharge measurements or daily mean flows at the nearby index station (Riggs, 1972) (fig. 2). The low-flow characteristics at partial-record stations then were estimated using the corresponding characteristics at the index

station (table 2). This methodology has been applied elsewhere in Puerto Rico (Santiago-Rivera, 1992, 1996, 1998).

Flow-duration characteristics were computed for the index station at Río Rosario (50136400), using techniques described by Searcy (1959); flow-duration characteristics were estimated for the partial-record stations using flow-duration characteristics of the index station in conjunction with the relation curve previously developed by correlation methods used for the low-flow study. All low-flow and flow-duration characteristics for the index station and partial-record stations were calculated without incorporating the effects of public water-supply withdrawals and (or) waste-water discharges upstream from stations. Estimated withdrawals and effluent discharges, however, were compiled from data furnished by the Puerto Rico Sewer Authority (PRASA) and reported by Black and Veatch (1996), and are presented in the header of each recording station in tables 1 and 2.

## Results and Interpretation

### Low Flow at a Continuous-Record Gaging Station

A continuous-record gaging station (index station) is a site where daily flow data are systematically collected over a period of years. A low-flow frequency curve was derived for one index station using the method described by Riggs (1972) and by adapting the log-Pearson Type III flood-frequency program described by the Interagency Advisory Committee on Water Data (1982). Examples of the methodology, as applied to Puerto Rico streams, are given in Santiago-Rivera (1992, 1996, 1998). The  $7Q_{10}$  and the  $7Q_2$  low-flow frequency characteristics computed for the index station used in this report are presented in table 1. The index station used in this analysis is affected by public water-supply withdrawals and waste-water treatment facilities discharges. During the time of this study, public water-supply withdrawals upstream from the index station were estimated at 1.1 cubic foot per second ( $\text{ft}^3/\text{s}$ ), and waste-water return flow was estimated at  $0.10 \text{ ft}^3/\text{s}$  (W. Molina, U.S. Geological Survey, written commun., 2000). The net stream low-flow capture of  $1.0 \text{ ft}^3/\text{s}$  upstream from the index station can result in computational underestimates of low-flow statistics at partial-record sites, for which gaging station Río Rosario near Hormigueros (50136400) was used as the index station. As no alternate gaging station exists in the vicinity of the study area, the user of the flow statistics should take into consideration that stated discharge rates could be underestimated by 10 to 15 percent.

### Low Flow at Partial-Record Stations

A partial-record station is a site where limited streamflow and (or) water-quality data are collected systematically over a period of time for use in hydrologic analysis. At these stations, sufficient base-flow measurements are made to define an adequate relation with concurrent flows at a nearby index station. Low-flow characteristics for partial-record stations were estimated using the graphical correlation technique of Riggs (1972) (fig. 2). This technique relates base-flow discharge measurements made at partial-record stations with concurrent flows measured at the index station. This estimating technique transfers low-flow characteristics computed by the log-Pearson Type III frequency distribution for the index station to the graphically determined relation curve to determine the corresponding low-flow characteristics at the partial-record stations (fig. 2) (Santiago-Rivera, 1998). Low-flow characteristics were estimated for 20 partial-record stations and are presented in table 2. Partial-record stations are located within the same geographic area of the index station; ideally the partial- and continuous-record stations should have similar drainage-basin land-use characteristics and geologic setting. In general, the drainage areas throughout the study area consist mostly of secondary forest with moderate agricultural activity, and are underlain by igneous rocks of low permeability. At these stations, streamflow was measured concurrently eight times at different base-flow recessions from March 2000 to March 2002. Instantaneous streamflow measurements made at partial-record stations are presented in Díaz and others (2000, 2001).

### Flow-Duration Characteristics

A flow-duration characteristic is the daily mean discharge for a given stream that has been exceeded for a specified percentage of days during the period of record. Flow-duration characteristics were computed for the index station using techniques developed by Searcy (1959). The analysis of the index station was based on daily streamflow records for complete water years (from October 1 to September 30), and the results are presented in table 1. Flow-duration characteristics were estimated for 20 partial-record stations using flow-duration characteristics derived for the index station in conjunction with the relation curves developed for the low-flow study. Index station discharges for the 99-, 95-, and 90-percent flow duration were used as the explanatory variable in the relation curve to estimate the discharges for the corresponding percent-duration points at the 20 partial-record stations (table 2).









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**Table 2.** Summary of drainage-basin, low-flow, and flow-duration estimates for partial-record stations within the municipio of Mayagüez, Puerto Rico.

[Lat, latitude; long, longitude; mi, mile; km, kilometer; mi<sup>2</sup>, square mile; km<sup>2</sup>, square kilometer; Mgal/d, million gallons per day; <, less than]

### RÍO GUANAJIBO BASIN 50135950 Río Rosario at Limón, Puerto Rico

LOCATION--Lat 18°10'33", long 67°03'07", Hydrologic Unit 21010003 at barrio Limón, 3.4 mi (5.5 km) southwest of Pico San Bernardo, 1.8 mi (2.9 km) northwest of El Cerro Avispa, and 2.4 mi (3.9 km) southeast of Represa de Mayagüez.

DRAINAGE AREA--14.6 mi<sup>2</sup> (37.8 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--A diversion of 0.72 Mgal/d is made upstream from station for public-water supply and 0.06 Mgal/d is recovered from waste-water treatment plant return flow.

#### LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	8.8
7-day, 10-year	5.6

#### FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	6.3	8.3	10

### 50138150 Río Hondo at Río Hondo, Puerto Rico

LOCATION--Lat 18°09'59", long 67°07'17", Hydrologic Unit 21010003 at barrio Río Hondo, 3.6 mi (5.8 km) northwest of Los Peñones, 3.7 mi (6.0 km) southwest of Represa de Mayagüez, and 2.6 mi (4.2 km) northwest of Rosario plaza.

DRAINAGE AREA--1.61 mi<sup>2</sup> (4.17 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--None.

#### LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	0.2
7-day, 10-year	0.1

#### FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	0.1	0.2	0.3

**Table 2.** Summary of drainage-basin, low-flow, and flow-duration estimates for partial-record stations within the municipio of Mayagüez, Puerto Rico.—Continued

RÍO GUANAJIBO BASIN—Continued  
50138190 Río Hondo near Mayagüez, Puerto Rico

LOCATION--Lat 18°09'53", long 67°08'32", Hydrologic Unit 21010003 at barrio Guanajibo, 2.0 mi (3.2 km) northwest of Hormigueros plaza, 1.8 mi (2.9 km) east of Cerro Cornelia, and 2.9 mi (4.7 km) south of Mayagüez plaza.

DRAINAGE AREA--2.93 mi<sup>2</sup> (7.59 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--None.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	0.2
7-day, 10-year	0.1

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	0.1	0.2	0.3

QUEBRADA SÁBALOS BASIN  
50138285 Quebrada Grande at Quebrada Grande, Puerto Rico

LOCATION--Lat 18°10'44", long 67°06'56", Hydrologic Unit 21010003 at barrio Quebrada Grande, 2.9 mi (4.7 km) southwest of Represa de Mayagüez, 3.6 mi (5.8 km) northwest of Los Peñones, and 2.6 mi (4.2 km) northwest of Rosario plaza.

DRAINAGE AREA--0.72 mi<sup>2</sup> (1.86 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--None.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	0.2
7-day, 10-year	0.1

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	0.1	0.2	0.3

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**Table 2.** Summary of drainage-basin, low-flow, and flow-duration estimates for partial-record stations within the municipio of Mayagüez, Puerto Rico.—Continued

QUEBRADA SÁBALOS BASIN—Continued  
50138375 Caño Majagual at Highway 348, Puerto Rico

LOCATION--Lat 18°11'32", long 67°08'15", Hydrologic Unit 21010003 at barrio Quebrada Grande, 3.3 mi (5.3 km) northeast of Cerro Cornelia, 3.5 mi (5.6 km) northwest of Hormigueros plaza, and 0.8 mi (1.3 km) southeast of Mayagüez plaza.

DRAINAGE AREA--0.20 mi<sup>2</sup> (0.52 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARK.--None.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	< 0.1
7-day, 10-year	< 0.1

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	< 0.1	< 0.1	< 0.1

RÍO YAGÜEZ BASIN  
50138400 Río Yaguez at Montoso, Puerto Rico

LOCATION--Lat 18°12'06", long 67°02'30", Hydrologic Unit 21010003 at barrio Montoso, 1.6 mi (2.6 km) south of Pico San Bernardo, 3.0 mi (4.8 km) northwest of El Cerro Avispa, and 2.4 mi (3.9 km) northeast of Represa de Mayagüez.

DRAINAGE AREA--0.63 mi<sup>2</sup> (1.63 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--Consumo pump station is not in use.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	0.5
7-day, 10-year	0.3

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	0.4	0.5	0.6

**Table 2.** Summary of drainage-basin, low-flow, and flow-duration estimates for partial-record stations within the municipio of Mayagüez, Puerto Rico.—Continued

RÍO YAGÜEZ BASIN—Continued  
50138425 Río Yagüez at Naranjales, Puerto Rico

LOCATION--Lat 18°12'08", long 67°03'00", Hydrologic Unit 21010003 at barrio Naranjales, 3.2 mi (5.1 km) northwest of El Cerro Avispa, 1.6 mi (2.6 km) southwest of Pico San Bernardo, and 1.9 mi (3.0 km) northeast of Represa de Mayagüez.

DRAINAGE AREA--1.32 mi<sup>2</sup> (3.42 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--None.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	1.1
7-day, 10-year	0.8

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	0.8	1.1	1.3

50138500 Río Yagüez at Presada de Mayagüez, Puerto Rico

LOCATION--Lat 18°12'02", long 67°04'42", Hydrologic Unit 21010003 at barrio Bateyes, 2.9 mi (4.7 km) southwest of Pico San Bernardo, 4.2 mi (6.8 km) northwest of El Cerro Avispa, and 2.5 mi (4.0 km) north of Rosario plaza.

DRAINAGE AREA--4.38 mi<sup>2</sup> (11.3 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--One hundred percent of the flow is diverted to Ponce de León filtration plant during low-flow periods.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	2.7
7-day, 10-year	1.7

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	1.9	2.6	3.2

## 14 Surface-Water, Water-Quality, and Ground-Water Assessment of the Municipio of Mayagüez, Puerto Rico, 1999-2002

**Table 2.** Summary of drainage-basin, low-flow, and flow-duration estimates for partial-record stations within the municipio of Mayagüez, Puerto Rico.—Continued

RÍO YAGÜEZ BASIN—Continued  
50138785 Quebrada Gandel at Mayagüez Arriba, Puerto Rico

LOCATION--Lat 18°12'42", long 67°06'57", Hydrologic Unit 21010003 at Mayagüez Arriba, 4.0 mi (6.4 km) northwest of Rosario plaza, 2.6 mi (4.2 km) southwest of Cerro Leclerc, and 2.6 mi (4.2 km) northwest of Represa de Mayagüez.

DRAINAGE AREA--1.83 mi<sup>2</sup> (4.74 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--None.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	0.6
7-day, 10-year	0.3

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	0.4	0.6	0.8

50138800 Río Yagüez near Mayagüez, Puerto Rico

LOCATION--Lat 18°12'32", long 67°05'07", Hydrologic Unit 21010003 at steel-truss bridge about 800 ft (244 m) south of Highway 106, 1.8 mi (2.9 km) west of Highways 106 and 352 junction, and 1.4 mi (2.2 km) east northeast from Mayagüez plaza.

DRAINAGE AREA--4.15 mi<sup>2</sup> (11 km<sup>2</sup>). Does not include area upstream from station 50138500 Río Yagüez at Presada de Mayagüez.

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--Río Yagüez basin drainage area (4.38 mi<sup>2</sup>) upstream from Presada de Mayagüez does not contribute any flow during low-flow periods to station 50138800 Río Yagüez near Mayagüez, because all flow is diverted to Ponce de León filtration plant.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	2.3
7-day, 10-year	1.4

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	1.6	2.2	2.7



**Table 2.** Summary of drainage-basin, low-flow, and flow-duration estimates for partial-record stations within the municipio of Mayagüez, Puerto Rico.—Continued

RÍO YAGÜEZ BASIN—Continued  
50138815 Quebrada Caricosa near Represa de Mayagüez, Puerto Rico

LOCATION--Lat 18°11'27", long 67°05'18", Hydrologic Unit 21010003 at barrio Juan Alonso, 0.9 mi (1.4 km) southwest of Represa de Mayagüez, 2.9 mi (4.7 km) northwest of Los Peñones, and 1.9 mi (3.0 km) northwest of Rosario plaza.

DRAINAGE AREA--0.57 mi<sup>2</sup> (1.48 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--None.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	< 0.1
7-day, 10-year	< 0.1

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	< 0.1	< 0.1	< 0.1

50138840 Quebrada Caricosa near Mayagüez, Puerto Rico

LOCATION--Lat 18°11'50", long 67°06'45", Hydrologic Unit 21010003 at barrio Juan Alonso, 2.3 mi (3.7 km) southwest of Represa de Mayagüez, 2.9 mi (4.7 km) southwest of Cerro Leclerc, and 3.1 mi (5.0 km) northwest of Rosario plaza.

DRAINAGE AREA--2.40 mi<sup>2</sup> (6.22 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--None.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	0.7
7-day, 10-year	0.4

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	0.5	0.7	0.9

**16 Surface-Water, Water-Quality, and Ground-Water Assessment of the Municipio of Mayagüez, Puerto Rico, 1999-2002**

**Table 2.** Summary of drainage-basin, low-flow, and flow-duration estimates for partial-record stations within the municipio of Mayagüez, Puerto Rico.—Continued

RÍO YAGÜEZ BASIN—Continued  
50138845 Tributario de Quebrada Caricosa at Highway 105, Puerto Rico

LOCATION--Lat 18°11'48", long 67°06'56", Hydrologic Unit 21010003 at Mayagüez Arriba, 2.5 mi (4.0 km) southwest of Represa de Mayagüez, 3.1 mi (5.0 km) southwest of Cerro Leclerc, and 3.2 mi (5.1 km) northwest of Rosario plaza.

DRAINAGE AREA--0.17 mi<sup>2</sup> (0.44 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--None.

LOW-FLOW CHARACTERISTICS			
	Low-flow characteristics	Discharge (cubic feet per second)	
	7-day, 2-year	< 0.1	
	7-day, 10-year	< 0.1	

  

FLOW-DURATION CHARACTERISTICS			
Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	< 0.1	< 0.1	< 0.1

50138860 Quebrada Caricosa at mouth, Puerto Rico

LOCATION--Lat 18°12'31", long 67°07'27", Hydrologic Unit 21010003 at Mayagüez Arriba, 3.1 mi (5.0 km) northwest of Represa de Mayagüez, 3.2 mi (5.1 km) southwest of Cerro Leclerc, and 4.2 mi (6.8 km) northwest of Rosario plaza.

DRAINAGE AREA--2.92 mi<sup>2</sup> (7.56 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--None.

LOW-FLOW CHARACTERISTICS			
	Low-flow characteristics	Discharge (cubic feet per second)	
	7-day, 2-year	0.8	
	7-day, 10-year	0.4	

  

FLOW-DURATION CHARACTERISTICS			
Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	0.5	0.8	1.0

**Table 2.** Summary of drainage-basin, low-flow, and flow-duration estimates for partial-record stations within the municipio of Mayagüez, Puerto Rico.—Continued

QUEBRADA DEL ORO BASIN  
50139625 Quebrada del Oro at Miradero, Puerto Rico

LOCATION--Lat 18°13'15", long 67°08'00", Hydrologic Unit 21010003 at barrio Miradero, 2.0 mi (3.2 km) southeast of Peña Cortada, 4.9 mi (7.9 km) northeast of Cerro Cornelia, and 2.3 mi (3.7 km) northeast of Mayagüez plaza.

DRAINAGE AREA--0.69 mi<sup>2</sup> (1.79 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--None.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	0.2
7-day, 10-year	0.1

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	0.1	0.2	0.3

50139650 Quebrada del Oro at Highway 2, Puerto Rico

LOCATION--Lat 18°12'50", long 67°08'48", Hydrologic Unit 21010003 at Highway 2, 0.8 mi (1.3 km) upstream from mouth, 4.0 mi (6.4 km) northeast of Cerro Cornelia, and 0.9 mi (1.4 km) northwest of Mayagüez plaza.

DRAINAGE AREA--1.49 mi<sup>2</sup> (3.86 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--None.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	0.8
7-day, 10-year	0.5

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	0.5	0.7	0.9

## 18 Surface-Water, Water-Quality, and Ground-Water Assessment of the Municipio of Mayagüez, Puerto Rico, 1999-2002

**Table 2.** Summary of drainage-basin, low-flow, and flow-duration estimates for partial-record stations within the municipio of Mayagüez, Puerto Rico.—Continued

**RÍO GRANDE DE AÑASCO BASIN**  
50145390 Río Casey at Río Cañas Arriba, Puerto Rico

LOCATION--Lat 18°14'58", long 67°04'00", Hydrologic Unit 21010003 at barrio Río Cañas Arriba, 2.3 mi (3.7 km) northwest of Pico San Bernardo, 1.9 mi (3.0 km) northeast of Cerro Leclerc, and 3.4 mi (5.5 km) northeast of Represa de Mayagüez.

DRAINAGE AREA--7.03 mi<sup>2</sup> (18.2 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--None.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	6.2
7-day, 10-year	4.2

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	4.7	6.0	7.0

50146015 Río Cañas at Camino Charluisant, Puerto Rico

LOCATION--Lat 18°12'57", long 67°02'48", Hydrologic Unit 21010003 at barrio Río Cañas Arriba, 0.6 mi (1.0 km) southwest of Pico San Bernardo, 2.2 mi (3.5 km) southeast of Cerro Leclerc, and 2.3 mi (3.7 km) northeast of Represa de Mayagüez.

DRAINAGE AREA--1.76 mi<sup>2</sup> (4.56 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--None.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	0.9
7-day, 10-year	0.5

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	0.6	0.8	1.0

**Table 2.** Summary of drainage-basin, low-flow, and flow-duration estimates for partial-record stations within the municipio of Mayagüez, Puerto Rico.—Continued

RÍO GRANDE DE AÑASCO BASIN—Continued  
50146035 Río Cañas at Highway 352, Puerto Rico

LOCATION--Lat 18°14'10", long 67°05'28", Hydrologic Unit 21010003 at barrio Río Cañas Arriba, 3.3 mi (5.3 km) northwest of Pico San Bernardo, 1.2 mi (1.9 km) northwest of Cerro Leclerc, and 2.6 mi (4.2 km) northwest of Represa de Mayagüez.

DRAINAGE AREA--5.83 mi<sup>2</sup> (15.1 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--None.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	4.2
7-day, 10-year	2.7

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	3.0	4.0	4.9

50146036 Río Cañas upstream of Quebrada Cojolla, Puerto Rico

LOCATION--Lat 18°14'08", long 67°06'01", Hydrologic Unit 21010003 at barrio Río Cañas Abajo, 4.3 mi (6.9 km) northwest of Pico San Bernardo, 2.0 mi (3.2 km) northwest of Cerro Leclerc, and 3.1 mi (5.0 km) northwest of Represa de Mayagüez.

DRAINAGE AREA--6.18 mi<sup>2</sup> (16.0 km<sup>2</sup>).

LOW-FLOW AND FLOW-DURATION ESTIMATES--Based on correlation of eight base-flow measurements with concurrent base flows at gaging station 50136400.

REMARKS--PRASA intake is located downstream from station 50146036. All flow is diverted to Miradero filtration plant during low-flow periods.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics	Discharge (cubic feet per second)
7-day, 2-year	4.2
7-day, 10-year	2.7

FLOW-DURATION CHARACTERISTICS

Discharge, in cubic feet per second, which was exceeded for indicated percentage of days			
Percent	99	95	90
Discharge	3.0	3.9	4.8

## 20 Surface-Water, Water-Quality, and Ground-Water Assessment of the Municipio of Mayagüez, Puerto Rico, 1999-2002

**Table 3.** Principal features of public water-supply filtration plants, surface-water intakes, a public waste-water treatment facility, and treated waste-water outlets within the municipio of Mayagüez, Puerto Rico.

[Mgal/d, million gallons per day; est., estimate; --, no data or not applicable]

Public water-supply filtration plants and surface-water intakes (plate 1)	Latitude	Longitude	Safe yield (Mgal/d)	Water available for use (Mgal/d)	Mean daily withdrawal rate (Mgal/d)	Source stream
Río Yagüez gravity intake	--	--	<sup>1</sup> 0.53	<sup>2</sup> 1.23	--	Río Yagüez
Río Cañas gravity intake	--	--	<sup>1</sup> 0.68	<sup>2</sup> 1.94	--	Río Cañas
Río Grande de Añasco intake pump	--	--	--	--	--	Río Grande de Añasco
Miradero filtration plant	18°13'42"	67°08'25"	--	--	<sup>3</sup> 18.8	Río Cañas and Río Grande de Añasco
Ponce de León filtration plant (PRASA Vieja)	18°12'17"	67°07'36"	--	--	<sup>3</sup> 1.4	Río Yagüez

  

Public waste-water treatment facilities and effluent-discharge points (plate 1)	Latitude	Longitude	Discharge capacity (Mgal/d)	Mean daily discharge rate (est. 2000) (Mgal/d)	Receiving stream
Mayagüez regional waste-water treatment plant	18°15'07"	67°09'30"	--	--	--
Mayagüez regional waste-water treatment plant ocean outfall	18°14'33"	67°11'27"	--	10.7	Bahía de Mayagüez
Alturas de Mayagüez (closed in 1988)	18°14'22"	67°09'34"	--	--	Caño Boquilla
Guanajibo Homes (closed in 1987)	18°10'45"	67°10'13"	--	--	Caño Corazones
Valle Hermoso (closed in 1987)	18°09'34"	67°09'17"	--	--	Río Hondo
Zona Libre (Sábalos) (closed in 1987)	18°10'26"	67°09'10"	--	--	Caño Merle

<sup>1</sup> Black and Veatch (1996).

<sup>2</sup> Given value is the Q-99 flow-duration estimate obtained in this assessment.

<sup>3</sup> Reported by Compañía de Aguas de Puerto Rico for calendar year 2000.

# Chapter B: Sanitary Quality of Surface Water During Base-Flow Conditions in the Municipio of Mayagüez, Puerto Rico, 2000-01

By Senén Guzmán-Ríos, Fernando Gómez-Gómez, and Mario L. Oliveras-Feliciano

## Purpose and Scope

A survey of stream sanitary quality was conducted by the USGS in cooperation with the municipio of Mayagüez, to define the extent of fecal contamination in streams. The assessment was made by obtaining and analyzing samples for fecal coliform and fecal streptococcus bacteria from 37 stream locations during base-flow conditions between July and November 2000, in April 2001, and in February 2002. Although the synoptic surveys were conducted in streams that have headwaters outside the municipio boundary, most of the sampling was conducted within the territorial limits of the municipio of Mayagüez. This chapter describes the methods and techniques used in conducting the survey at the 37 sampling stations, and provides interpretations of the fecal coliform and fecal streptococcus indicator bacteria concentrations by developing a classification procedure to rank the sanitary quality of stream courses. The data were incorporated into a thematic map (plate 1) that also includes other important hydrologic features that (a) serve as an initial source of information to guide future efforts by municipal and Commonwealth authorities in implementing measures to enhance the sanitary quality of contaminated streams and conserve those with an acceptable quality; and (b) provide reliable scientific information to planners and managers of the water and biological resources.

The sampling network within the municipio of Mayagüez was divided into six drainage basins. These basins are: Upper Río Guanajibo, Caño Corazones, Río Yagüez, Quebrada del Oro, Caño Boquilla, and Río Grande de Añasco.

## Background

Water-quality standards for surface waters in Puerto Rico have been established by the Puerto Rico Environmental Quality Board (Junta de Calidad Ambiental de Puerto Rico, 1990) on the basis of the designated use (for example, fishing,

source of raw water for public supply, and secondary contact recreation, among others). All perennial fresh surface waters in Puerto Rico inland of their estuary segments have been classified as Class SD waters. This classification includes surface water intended for use (or potential use) as a raw source of public water supply, for propagation and preservation of desirable aquatic species, and for primary (swimming) and secondary (boating and fishing) contact recreation. The sanitary quality standard for Class SD surface water is based on the fecal coliform or total coliform indicator bacteria (Junta de Calidad Ambiental de Puerto Rico, 1990). All coastal water bodies within the territorial limits of the municipio of Mayagüez (Caños Boquilla, Majagual, Merle, and Corazones), and the estuary segments of Río Guanajibo, Río Yagüez, and Río Grande de Añasco are designated as Class SB surface waters. Class SB-designated use waters are intended for use in primary and secondary recreation and for the propagation and preservation of desirable aquatic species. This designated use also applies to the coastline at Mayagüez from the mean tide level to a distance up to 1,650 ft (500 meters) offshore north of Punta Algarrobo (plate 1). Along the coast from Punta Algarrobo to Punta Guanajibo and extending offshore 10.3 nautical miles, the coastal waters are designated as Class SC surface waters. Class SC surface waters are intended for use where human contact with the water is indirect (such as fishing or boating), and for use in the propagation and preservation of desirable species.

Fecal coliform bacteria are used as an indicator of pathogens in surface waters and to indicate the potential for public health problems. There is abundant epidemiological evidence of gastrointestinal disorders that result from the ingestion of contaminated surface water. Contact with contaminated water can lead to ear or skin infections, and inhalation of contaminated water can cause respiratory diseases. Typical concentrations of two common indicator bacteria in contaminated water are given in table 4. Fecal coliform (FC) and fecal streptococcus (FS) bacteria are native to the intestines of warm-blooded animals, including humans, and are considered non-pathogenic. However, these bacteria























The field replicate sample is used to measure the precision of the entire process (for example, dilution procedures and variability of bacteriological concentrations resulting from dip sampling). Field replicate samples collected and analyzed during this study represented 21 percent of the number of primary samples collected. Precision of field data is measured by comparing the results of the primary samples with the field replicate samples. Relative percent difference (RPD) of primary and replicate samples are calculated as:

$$RPD = S_1 - S_2 / [(S_1 + S_2) / 2] \times 100,$$

where

- RPD* is the relative percent difference,  
*S<sub>1</sub>* is the primary sample value, and  
*S<sub>2</sub>* is the field replicate sample value.

The analytical results indicate that the RPD of the sequential replicate samples obtained as part of this survey ranged from about 3 to 67 percent with a median value of 14 percent (table 5).

Filter blanks were obtained by placing a sterile, gridded-membrane filter on the funnel base and rinsing the funnel of the filtration assembly equipment with 100 mL of sterile buffered water. This filter blank is processed through the filtration equipment before the water sample is filtered. The result of the

analysis of the filter blank should be negative (no development of colonies); if positive, then the filtration equipment was not sterile.

A procedure blank, which measures the effectiveness of the rinsing techniques, was obtained by placing a sterile, gridded-membrane filter on the funnel base and rinsing the funnel of the filtration assembly equipment with 100 mL of sterile buffered water. This blank was collected and processed after collecting and processing all other samples. The result of this analysis should be negative; the positive presence of indicator colonies on the procedure blank indicates either inadequate rinsing or contamination of equipment or buffered water during sample processing.

In summary, results for filter, field, and procedure blank samples, which are measures of the effectiveness of sterilization, should be negative; if results were positive, then analytical results of samples obtained between negative QA/QC blanks (before and after the positive blank) were reviewed for suspect data results (for example, high counts or significant discrepancy between the number of colonies developed for sample dilutions with ideal and non-ideal counts). During this study, no bacteriological results were discarded. The results of the analysis of sterile buffered water, filter, field, and procedure blanks conducted during the study were negative (showed no development of colonies).

**Table 5.** Relative percent difference for fecal coliform bacteria counts between primary and field replicate samples collected at streams in the municipio of Mayagüez, Puerto Rico, 2000-2002.

[*S<sub>1</sub>*, primary sample value; *S<sub>2</sub>*, field replicate sample value; RPD relative percent difference]

Station number	Station name	<i>S<sub>1</sub></i>	<i>S<sub>2</sub></i>	RPD
50135950	Río Rosario at Limón	610	740	19
50138190	Río Hondo near Mayagüez	88	110	22
50138500	Río Yagüez at Presada	190	200	5
		2,100	3,400	47
		72	83	14
		80	84	5
50138800	Río Yagüez near Mayagüez	100	150	40
50138860	Quebrada Caricosa at mouth	280	217	25
		780	760	3
		230	200	14
50145390	Río Casey at Río Cañas Arriba	230	200	14
50146036	Río Cañas upstream Quebrada Cojolla	490	390	23
		8,700	9,100	4
		100	200	67
		120	160	29
50146045	Río Cañas at Represa	2,800	3,000	7
		270	300	10
		61	68	11
		88	84	5

## Results and Interpretation

A major assumption in the interpretation is that streamflow during low-flow conditions is derived from ground-water discharge, and that the fecal contamination during stream base-flow conditions is primarily derived from sources discharging directly into stream courses or near the riparian zone. It is also assumed that, with an average of two samples obtained at least several months apart during stream low-flow recession periods at numerous locations throughout a watershed, it is possible to define, on a qualitative basis, the relative sanitary quality at the site with respect to the other sampling locations.

Based on these assumptions, the analytical results for fecal coliform and fecal streptococcus bacteria concentrations from the 37 stream sampling stations are used to characterize the sanitary quality of about 175 miles of perennial stream channels within the municipio of Mayagüez (table 5). The sanitary quality of approximately 8 stream miles could not be assessed using indicator bacteria data, because streamflow was slow or non-existent (stagnant). These 8 stream miles are primarily drainage canals located in the lower part of Caño Corazones basin within the municipio de Mayagüez.

A relative ranking of the stream sanitary quality was used to delimit stream channels as being either **good**, **acceptable**, **fair**, or **poor** (Rodríguez and others, 2002) (table 6). This relative ranking was established using the Puerto Rico Water Quality Standards for fecal coliform of 2,000 col/100 mL, in use during the study, and the following rationale: if both samples had fecal coliform bacteria concentrations less than 200 col/100 mL and fecal streptococcus concentrations less than 400 col/100 mL, then the **good** classification was assigned to the sampling station. The stream segment given the same classification was extended upstream and downstream as follows.

If the upstream and/or downstream reach within the same order stream had been sampled and the results were comparable, then the same classification was given for the entire stream segment between both sampling stations; if the upstream station and/or downstream station was classified differently, then the classification was extended to the mid-point of the stream; and if no other sampling station was located upstream, then the same classification was extended upstream not more than 0.6 mi (1.0 km) along the main trunk of the stream. For stream segments with an upstream distance greater than 0.6 mi from the sampling station and for its tributaries, the same classification was assigned, but using the terminology of

**presumed good**. If no other sampling station was established downstream, then 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 **presumed good** classification assigned downstream of the 0.6-mi distance. The **presumed** ranking was not assigned to any stream (or tributary) in which no fecal coliform and fecal streptococcus analyses were obtained, given the low likelihood of bacteriological concentrations being within the classification of **good** or **presumed good**.

For sampling stations where fecal coliform bacteria concentrations were equal to or less than 2,000 col/100 mL on both sampling occasions, stream segments were classified as **acceptable**. The classification of **presumed acceptable** was assigned for stream segments upstream and downstream of the sampling station using the same rationale described previously.

For sampling stations where fecal coliform bacteria concentrations were equal to or greater than 2,000 col/100 mL for one sampling occasion, but less than 2,000 col/100 mL for the second sampling, stream segments were classified as **fair**. The classification of **presumed fair** was extended upstream and downstream of the sampling station following the same rationale as stated previously for **good** and **presumed good**.

Sampling stations with fecal coliform bacteria concentrations greater than 2,000 col/100 mL for both sample dates were considered **poor**. Within the city of Mayagüez, an exception was made where the stream classification of **presumed poor** was extended upstream to the urban limits and at various streams to the stream mouth. This classification was justified because four sampling stations were established within the urban reaches of streams; three of the stations had fecal coliform concentrations ranked as **poor** (stations 50139200, 50139625, 50139650) and eight samples collected had fecal coliform concentrations greater than 2,000 col/100 mL (concentrations ranged from 3,100 to 100,000 col/100 mL, table 7).

**Table 6.** Classification rationale used in ranking the sanitary quality of streams in the municipio of Mayagüez, Puerto Rico.

[>, greater than; <, less than; mL, milliliters; mi, mile; k, non-ideal bacteria count]

Ranking	Fecal coliform concentration for stream reach during base-flow conditions, in colonies per 100 mL	Rationale	Range of concentrations measured during synoptic surveys		
			Fecal coliform concentration, in colonies per 100 mL	Fecal streptococcus concentration, in colonies per 100 mL	
<b>Good</b>	< 200	Samples obtained at site also had fecal streptococcus concentrations less than 400 colonies per 100 mL.	<b>Maximum</b>	150	350
			<b>Minimum</b>	100	240
			<b>Geometric mean</b>	120	293
			<b>Number of samples</b>	3	3
<b>Presumed good</b>	< 200	Samples obtained at a distance greater than 0.6 mi upstream or downstream were used to infer that equal concentrations are probable within the delimited stream reach.	<b>Maximum</b>	160	370
			<b>Minimum</b>	50	70
			<b>Geometric mean</b>	98	180
			<b>Number of samples</b>	5	5
<b>Acceptable</b>	< or equal to (=) 2,000	Samples obtained within 0.6 mi upstream or downstream of delimited reach.	<b>Maximum</b>	900	2,600
			<b>Minimum</b>	k53	200
			<b>Geometric mean</b>	230	506
			<b>Number of samples</b>	47	47
<b>Presumed acceptable</b>	< or equal to (=) 2,000	Samples obtained at a distance greater than 0.6 mi upstream or downstream were used to infer that equal concentrations are probable within the delimited stream reach.	<b>Maximum</b>	370	510
			<b>Minimum</b>	210	460
			<b>Geometric mean</b>	260	490
			<b>Number of samples</b>	3	3
<b>Fair</b>	Equal probability for < or > 2,000	Samples obtained within 0.6 mi upstream or downstream of delimited reach.	<b>Maximum</b>	5,200	2,100
			<b>Minimum</b>	k58	k31
			<b>Geometric mean</b>	470	205
			<b>Number of samples</b>	6	5
<b>Presumed fair</b>	Equal probability for < or > 2,000	Samples obtained at a distance greater than 0.6 mi upstream or downstream were used to infer same conditions are likely within the delimited stream reach.	<b>Maximum</b>	0	0
			<b>Minimum</b>	0	0
			<b>Geometric mean</b>	0	0
			<b>Number of samples</b>	0	0
<b>Poor</b>	> 2,000	Samples obtained within 0.6 mi upstream or downstream of delimited reach.	<b>Maximum</b>	100,000	65,000
			<b>Minimum</b>	2,700	530
			<b>Geometric mean</b>	8,600	2,900
			<b>Number of samples</b>	12	12
<b>Presumed poor</b>	> 2,000	Samples obtained at a distance greater than 0.6 mi upstream or downstream of delimited stream reach were used to infer that similar concentrations are likely within delimited stream reach; also applied within stream reaches in the urbanized part of municipio of Mayagüez, since all three sampled sites in urban reaches of the stream had concentrations above 2,000 colonies per 100 mL.	<b>Maximum</b>	3,500	3,500
			<b>Minimum</b>	2,300	2,300
			<b>Geometric mean</b>	2,800	2,800
			<b>Number of samples</b>	2	2















































































