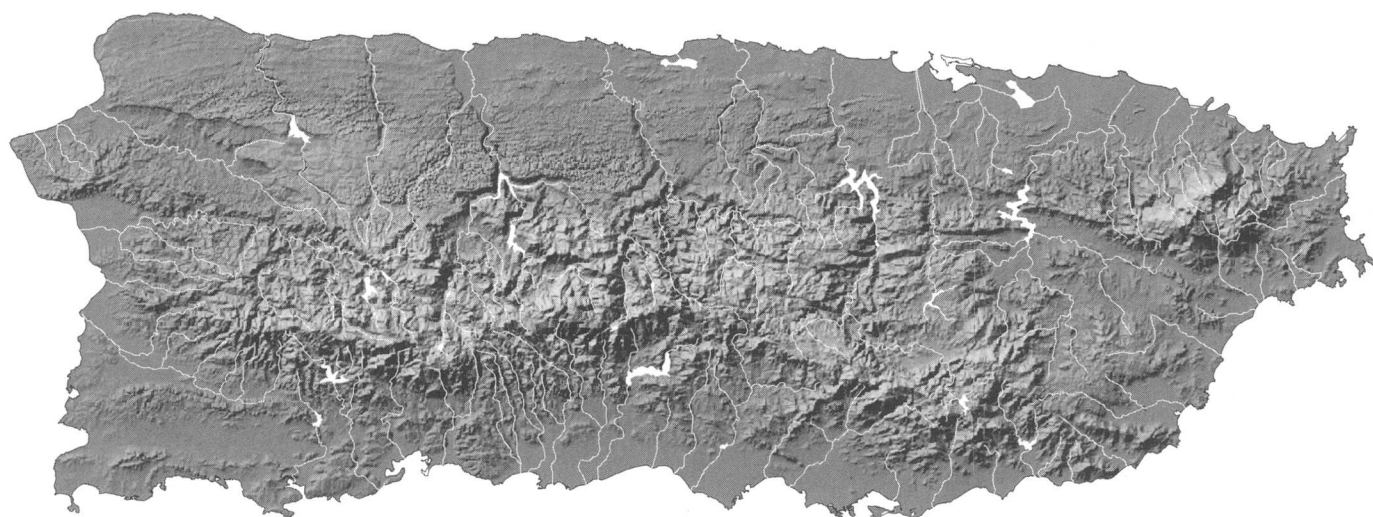


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PUERTO RICO AQUEDUCT AND SEWER AUTHORITY

Analysis of Flow Durations for Selected Streams in Puerto Rico Through 1994



Water-Resources Investigations Report 98-4189

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

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By James B. Atkins, Francisco Pérez-Blair, and James L. Pearman

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In cooperation with the
PUERTO RICO AQUEDUCT AND SEWER AUTHORITY

San Juan, Puerto Rico: 1999

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, VERTICAL DATUM, and ACRONYMS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
square mile (mi ²)	2.590	square kilometer
cubic foot per second (ft ³ /s)	0.02832	cubic meter per second

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 both the United States and Canada, formerly called Sea Level Datum of 1929.

Acronyms used in this report:

PRASA Puerto Rico Aqueduct and Sewer Authority
USGS U.S. Geological Survey

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Abstract

Flow-duration discharges were computed for 84 continuous-record streamflow-gaging stations in Puerto Rico, for which at least 5 years of daily-mean discharge record existed through the 1994 water year ending September 30, 1994. Daily-mean discharges were adjusted at 36 of these gaging stations based on water-use data for water-filtration plants and wastewater treatment plants. Flow-duration curves were computed utilizing the adjusted discharge record for the 36 of these gaging stations and represent the flow-duration discharge at a gaging station if water was not withdrawn or discharged into the stream by treatment plants upstream from the gaging station. In general, the flow-duration discharges for the adjusted streamflows were higher than the flow-duration discharges for the unadjusted streamflows, and indicate that more water is being withdrawn from the streams by water-filtration plants than is being discharged into the streams by wastewater treatment plants.

INTRODUCTION

Puerto Rico is an island with a surface area of 3,435 mi² and a population of approximately 3.5 million in 1990. Population on the island increased by 9 percent from 1980 to 1990; the population is expected to be 3.9 million by the year 2000 (U.S. Geological Survey, 1993), which corresponds to an

increase in the population of 11 percent. The increasing population along with expanding industrial development has placed significant demands on the island's water resources. In addition, from the summer of 1993 until the spring of 1995, Puerto Rico was subjected to drought conditions causing below average streamflows that resulted in public water supply and water distribution shortages.

Streamflow characteristics are often used to assess and manage the quantity and quality of surface-water resources. In Puerto Rico, water management agencies use flow-duration curves to assist in the design of water supplies and waste-allocation studies. Continued population growth and industrial expansion will require that adequate planning and management of water resources be implemented to ensure that extremely low streamflows do not result in more severe public water-supply shortages in the future.

In 1995, the U.S. Geological Survey (USGS), in cooperation with the Puerto Rico Aqueduct and Sewer Authority (PRASA), began a study of flow durations for streams in Puerto Rico. The study objectives were to compile existing streamflow data, compute the flow durations, and present the flow durations in a report.

Purpose and Scope

This report provides estimates of flow-duration discharge data for 84 continuous-record streamflow-gaging stations in Puerto Rico for which at least 5 years of daily-mean discharge data were available

through the 1994 water year¹. Daily discharge records for gaging stations located on streams which are affected by surface-water withdrawals or effluent discharges were adjusted by adding flows which were withdrawn from the stream or by subtracting flows which were discharged into the stream upstream of the gage. Flow-duration curves were then computed for the adjusted daily discharges and represented the flow-duration characteristics at a gaging station, if water was not withdrawn or discharged into the stream upstream from the gaging station. Of the 84 gaging stations presented in this report, 36 have adjusted streamflow record. Of the 36 stations with adjusted data, 20 were adjusted because of filtration-plant withdrawals only, one was adjusted because of wastewater-treatment plant effluent only, and 15 were adjusted for both filtration-plant withdrawals and wastewater-treatment plant effluent.

Previous Investigations

Quiñones and others (1984) described flow-duration discharges for 78 streamflow-gaging stations in Puerto Rico through the 1982 water year. In the Quiñones and others report, flow durations were computed for the entire periods of record as well as for individual months. The periods of record for the gaging stations used in that study ranged from 3 to 25 years.

Description of the Study Area

The area of this study is the island of Puerto Rico, which is bounded by the Atlantic Ocean to the north and the Caribbean Sea to the south. The island's principal streams flow from a central mountain range—the Cordillera Central—to the sea through a system of small rivers. Flow along the streams in the north coast area is perennial; however, many of the streams along the south coast have almost no flow during the

dry season. Only seven basins in Puerto Rico have drainage areas larger than 100 mi² and base flows throughout the island are generally less than 100 ft³/s (U.S. Geological Survey, 1986).

Average annual precipitation varies greatly, from as much as 250 in. in eastern Puerto Rico to as little as 30 in. in southwestern Puerto Rico. Annual precipitation averages about 75 in. along the north coast and less than 35 in. along the south coast. Precipitation on the island occurs more frequently during a spring rainfall period occurring in April and May and a wet season from August through November. Typically, a generally dry season begins in December and usually ends in March or April and an erratic, semi-dry period occurs in June and July. Approximately 55 percent of the average annual rainfall on Puerto Rico is lost to evapotranspiration. Average annual runoff ranges from about 20 in. in the north, due to regulation and withdrawals for public water supply, to about 150 in. in the rain forest of eastern Puerto Rico. Generally, a large part of the annual runoff occurs during August through December and during April and May (U.S. Geological Survey, 1986).

METHODS OF ANALYSIS

All existing daily streamflow data through the end of the 1994 water year for gaging stations with a minimum of 5 years of record (84 stations; fig. 1) were compiled and used to create a data base using the ANNIE data management system (Lumb and others, 1990). The streamflow-gaging stations used in the study are listed in table 1 and shown in figures 2 to 15 (pages 19 to 32). Of the 84 gaging stations used in the study, 50 stations had periods of record of 10 or more years duration. In addition, withdrawals from water-filtration plants and effluent discharges from wastewater treatment plants were compiled from data furnished by PRASA (1992) and Black and Veatch (1996).

¹A water year is defined as the 12-month period from October 1 to September 30; for example, the 1994 water year includes the period October 1, 1993, to September 30, 1994.

Table 1. Active and discontinued streamflow-gaging stations in Puerto Rico used in the study[--, indeterminate; mi², square miles]

USGS station number	Station name	Drainage area (mi ²)	Period of record (water years)
50010600	Río Guajataca above Lago Guajataca	--	1984-89
50011200	Río Guajataca below Lago Guajataca	--	1969-70 1984-87
50011400	Río Guajataca above mouth near Quebradillas	--	1969-70 1984-89
50014800	Río Camuy near Bayaney	--	1984-94
50015700	Río Camuy near Hatillo	--	1984-94
50021500	Río Pellejas near Utuado	9.55	1969-74
50023000	Río Viví near Central Pellejas	5.66	1969-74
50025155	Río Saliente at Coabey near Jayuya	9.25	1989-94
50027750	Río Grande de Arecibo above Arecibo	175	1982-94
50028000	Río Tanamá near Utuado	18.4	1959-94
50028400	Río Tanamá at Charco Hondo	57.6	1969-71 1981-94
50029000	Río Grande de Arecibo at Central Cambalache	200	1969-83
50030460	Río Orocovis near Orocovis	5.03	1981-82 1988-94
50031200	Río Grande de Manatí near Morovis	55.2	1965-94
50031500	Río Sana Muerto near Orocovis	3.68	1965-70
50033500	Río Bauta near Divisoria	3.68	1949-54
50034000	Río Bauta near Orocovis	16.7	1969-82 1988-94
50035000	Río Grande de Manatí at Ciales	128	1960-94
50038100	Río Grande de Manatí at Highway 2 near Manatí	197	1970-94
50038320	Río Cibuco below Corozal	15.1	1969-94
50039500	Río Cibuco at Vega Baja	99.1	1973-94
50040000	Río de la Plata at Lago Carite	8.2	1949-67
50043000	Río de la Plata at Proyecto La Plata	63.0	1960-94
50043800	Río de la Plata at Comerío	109	1988-94
50045010	Río de la Plata below La Plata Dam	173	1989-94
50046000	Río de la Plata at Highway 2 near Toa Alta	208	1960-94
50047850	Río de Bayamón near Bayamón	41.8	1964-70 1988-94
50048770	Río Piedras at El Señorial	7.49	1988-94
50049000	Río Piedras at Río Piedras	12.5	1971-82 1987-93
50049100	Río Piedras at Hato Rey	15.4	1988-94

Table 1. Active and discontinued streamflow-gaging stations in Puerto Rico used in the study--Continued

USGS station number	Station name	Drainage area (mi ²)	Period of record (water years)
50050900	Río Grande de Loíza at Quebrada Arenas	6.0	1977-94
50051150	Quebrada Blanca at El Jagual	3.25	1984-94
50051180	Quebrada Salvatierra nr San Lorenzo	3.74	1984-94
50051310	Río Cayaguas at Cerro Gordo	10.2	1977-94
50053050	Río Turabo at Borinquen	7.89	1984-90
50055000	Río Grande de Loíza at Caguas	89.8	1959-94
50056400	Río Valenciano near Juncos	16.4	1971-94
50057000	Río Guarabo at Gurabo	60.2	1959-94
50059050	Río Grande de Loíza below Damsite	209	1986-94
50061300	Río Canovanillas near Loíza	14.4	1967-73
50061800	Río Canóvanas near Campo Rico	9.84	1967-94
50062500	Río Herrera near Colonia Dolores	2.75	1966-73
50063250	Río Espíritu Santo above El Verde	2.13	1945-52
50063300	Río Espíritu Santo near El Verde	2.23	1945-52
50063440	Quebrada Sonadora near El Verde	1.01	1983-94
50063500	Quebrada Toronja at El Verde	0.06	1983-94
50063800	Río Espíritu Santo near Río Grande	8.62	1966-94
50064200	Río Grande near El Verde	7.31	1967-70 1972-82 1990-94
50065500	Río Mameyes near Sabana	6.88	1967-73 1983-94
50065700	Río Mameyes at Highway 191 at Mameyes	11.8	1967-85
50067000	Río Sabana at Sabana	3.96	1979-94
50071000	Río Fajardo near Fajardo	14.9	1961-94
50072000	Río Fajardo at Fajardo	21.6	1960-66
50073400	Quebrada Palma at Dagua	4.84	1972-77
50075000	Río Icacos near Naguabo	1.26	1945-53 1979-94
50077000	Río Blanco at Río Blanco	17.6	1972-77
50081000	Río Humacao at Las Piedras	6.65	1974-77 1987-94
50082800	Río Guayanés near Colonia Laura	4.69	1969-82
50090500	Río Maunabo at Lizas	5.38	1971-85 1991-94
50092000	Río Grande de Patillas near Patillas	18.3	1966-94
50093050	Río Grande de Patillas at Lago Patillas	25.6	1949-58

Table 1. Active and discontinued streamflow-gaging stations in Puerto Rico used in the study--Continued

USGS station number	Station name	Drainage area (mi ²)	Period of record (water years)
50100200	Río Lapa near Rabo del Buey	9.92	1988-94
50100450	Río Majada at La Plena	16.7	1988-94
50106100	Río Coamo at Coamo	43.5	1987-94
50108000	Río Descalabrado near Los Llanos	12.9	1966-69 1984-94
50110900	Río Toa Vaca above Lago Toa Vaca	7.64	1989-94
50111500	Río Jacaguas at Juana Díaz	49.8	1984-94
50112500	Río Inabón at Real Abajo	9.7	1964-70 1971-94
50113800	Río Cerrillos above Lago Cerrillos near Ponce	11.9	1988-94
50114000	Río Cerrillos near Ponce	17.8	1964-85 1991-94
50114390	Río Bucaná at Highway 14 bridge near Ponce	24.9	1987-94
50115000	Río Portugués near Ponce	8.82	1964-94
50121000	Río Tallaboa at Peñuelas	24.2	1959-82
50124000	Río Guayanilla near Guayanilla	18.5	1961-69
50124200	Río Guayanilla near Guayanilla	18.9	1981-94
50125790	Río Yauco at Luchetti Damsite	17.4	1946-51
50129500	Río Loco near Gúanica	21.0	1963-68
50136000	Río Rosario at Rosario	16.4	1960-65 1975-86
50136400	Río Rosario near Hormigueros	18.3	1985-94
50138000	Río Guanajibo near Hormigueros	120	1973-94
50141000	Río Yahuecas near Adjuntas	15.4	1946-66 1980-85
50142700	Río Prieto near Lares	14.2	1949-57
50144000	Río Grande de Añasco near San Sebastián	94.3	1963-94
50147800	Río Culebrinas at Highway 404 near Moca	71.2	1967-94

Flow-Duration Analysis

Flow-duration discharges are based on flow-duration curves which are developed for the 84 continuous-record gaging stations with 5 or more years of record using methods described by Searcy (1959). A flow-duration curve is a cumulative distribution of daily-mean discharges arranged to show the percentage of time specific discharges were equaled or exceeded during the gaging station's period of record. Flow-duration discharges are used for studying the flow characteristics of streams and for comparing hydrologic characteristics of one basin with another (Searcy, 1959). The shape of the flow-duration curve is affected by the hydrologic and geologic characteristics of a drainage basin. A curve with a steep slope represents a stream whose flow is primarily the result of direct surface runoff, whereas a curve with a flat slope represents a stream whose flow is significantly augmented with water released from surface- or ground-water storage. The slope of the lower end of the duration curve indicates the storage characteristics of the basin; a flat slope at the lower end indicates a large amount of storage and a steep slope indicates a small amount. Streams with large floodplain storage or that drain swamp areas tend to have a flat slope at the upper end of the curve.

The flow-duration discharges were computed using SWSTAT, a computer program used for interactive computation of surface-water statistics (A.M. Lumb, W.O. Thomas Jr., and K.M. Flynn, USGS, written commun., 1994), which separates daily-mean discharges into class intervals based on the total range of discharge at the station for the period of record. The number of days that flows occur in each class interval are counted, and the percentage of days that each class interval discharge was equaled or exceeded are computed. A flow-duration curve is plotted using the logarithms of the class interval discharges and the percentage of days that the flows exceeded the indicated discharges, as shown in figure 16.

Flow-duration curves represent only the period for which they are calculated. Flow-duration discharges computed for different periods at a single site are not considered equivalent,

because climatic conditions and subsequent streamflows during the different periods may not be the same. For example, all daily-mean discharges that were less than the 95-percent flow duration for a 10-year period may have occurred during a single 6-month period. The 95-percent flow duration for the 10-year period is then equal to the 50-percent duration discharge for the year containing that 6-month period. Likewise, if all daily discharges in the 6-month period were the lowest in 20 years, the same discharge may have been equaled or exceeded 97.5 of the time during the 20-year period. Although flow-duration discharges computed for different periods are not considered equivalent, the flow-duration curve can be used to estimate the percentage of time that selected discharges that occur in the future will be equaled or exceeded if the period of record used to compute the flow-duration curve is of sufficient length and if discharges during that period are considered to adequately represent long-term conditions (Ries, 1994).

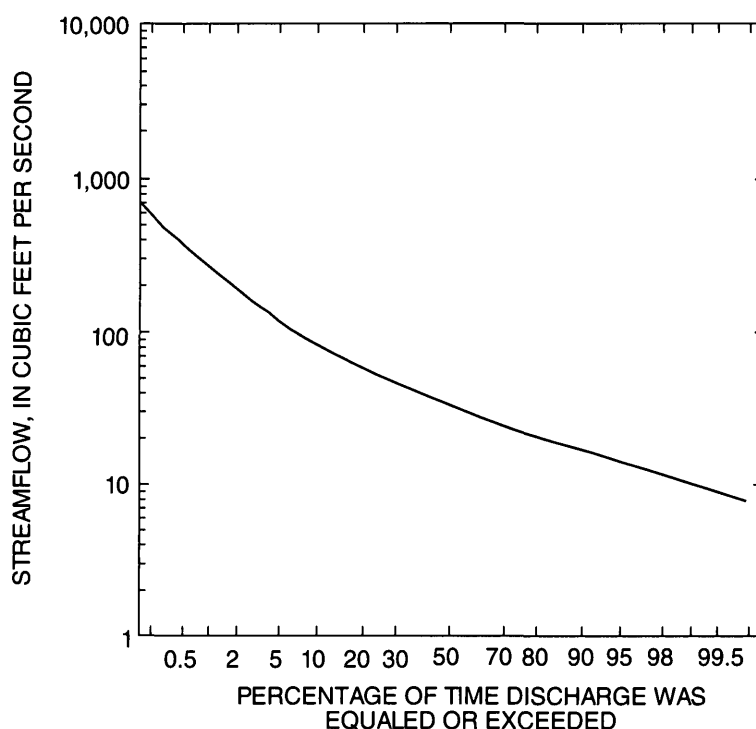


Figure 16. An example of a flow-duration curve for gaging station 50028000, Río Tanamá near Utuado, Puerto Rico, 1960-94.

Adjustments to Daily Discharge Record

Water-use data from the PRASA consisted of withdrawal rates for water-treatment filtration plants (Black and Veatch, 1996) and wastewater effluent discharge rates (PRASA, 1992). Water-use discharges were based on data during the 1991 calendar year. Because water-use data were not available for each year of each treatment plant's operation, the 1991 discharges were assumed to be constant for each treatment plant's period of operation. The daily streamflow at gaging stations for which treatment plants existed upstream was adjusted based on the treatment plant type. Flows recorded at water-filtration plants were added to the daily streamflow values, because the water-filtration plants always withdraw water from the stream. Flows recorded at wastewater treatment plants were subtracted from the daily streamflow values, because wastewater treatment plants always discharge water to the stream. The gaging stations affected by these two types of water treatment plants are listed in tables 2 and 3. Of the 36 stations with adjusted streamflow data, 20 were adjusted for filtration-plant withdrawals only, one was adjusted for wastewater-treatment plant effluent only, and 15 were adjusted for both filtration-plant withdrawals and wastewater treatment-plant effluent.

After the daily-mean discharges for the gaging stations were adjusted, flow-duration curves were computed for the adjusted daily discharge record. The flow-duration curves were developed using the methods presented earlier in the "Flow Duration Analysis" discussion of this report.

ESTIMATES OF FLOW-DURATION DISCHARGES

The flow-duration discharges for all stations included in this study are included in table 4. Flow-duration discharges for 36 stations with adjusted daily-mean discharge records are also included in table 4 and represent the flow-duration discharge at a gaging station, if water was not withdrawn or discharged into the stream by treatment plants upstream from the gaging station. In general, the flow-duration discharges for the adjusted streamflows were higher than the flow-duration discharges for the unadjusted streamflows. The higher flow-duration discharges indicate that more water is being withdrawn from the streams by the water-filtration plants than is being discharged into the streams by the wastewater treatment plants.

SUMMARY

Flow-duration discharges were computed for 84 continuous-record streamflow gaging stations in Puerto Rico for which at least 5 years of daily-mean discharge record existed through the 1994 water year. Daily-mean discharges were adjusted at 36 gaging stations, based on water-use data for water-filtration plants and wastewater treatment plants. Flow-duration curves were computed utilizing the adjusted discharge record for these 36 gaging stations and represent the flow-duration discharge at a gaging station, if water was not withdrawn or discharged into the stream by treatment plants upstream from the gaging station. In general, the flow-duration discharges for the adjusted streamflows were higher than the flow-duration discharges for the unadjusted streamflows and indicate that more water is being withdrawn from the streams by the water-filtration plants than is being discharged into the streams by the wastewater treatment plants.

Table 2. Gaging stations on selected streams in Puerto Rico affected by filtration-plant withdrawals

Station number	Station name	Filtration plant name	Municipality	Supplying stream
50010600	Río Guajataca above Lago de Guajataca	Lares 1	Lares	Río Guajataca
50011400	Río Guajataca above mouth near Quebradillas	Quebradillas	Quebradillas	Río Guajataca
50014800	Río Camuy near Bayaney	Quebrada	Hatillo	Río Camuy
		Lares 2	Lares	Río Camuy
50015700	Río Camuy near Hatillo	Quebrada	Hatillo	Río Camuy
		Lares 2	Lares	Río Camuy
50021500	Río Pellejas near Utuado	Vegas Arriba	Adjuntas	Río Pellejas
50025155	Río Saliente at Coabey near Jayuya	Coabey	Jayuya	Río Saliente
50028400	Río Tanamá at Charco Hondo	Arecibo	Arecibo	Río Tanamá
50029000	Río Grande de Arecibo at Central Cambalache	Arecibo	Arecibo	Río Tanamá
50030460	Río Orocovis near Orocovis	Orocovis 1	Orocovis	Río Orocovis
		Orocovis 2	Orocovis	Río Orocovis
50031200	Río Grande de Manatí near Morovis	Orocovis 1	Orocovis	Río Orocovis
		Orocovis 2	Orocovis	Río Orocovis
50035000	Río Grande de Manatí at Ciales	Negros	Corozal	Río Grande de Manatí
		Orocovis 1	Orocovis	Río Orocovis
		Orocovis 2	Orocovis	Río Orocovis
		Sana Muerto	Orocovis	Río Sana Muerto
		Negros	Corozal	Río Grande de Manatí
50038100	Río Grande de Manatí at Highway 2 near Manatí	Frontón Viejo	Ciales	Río Yunes
		Ciales	Ciales	Río Cialitos
		Orocovis 1	Orocovis	Río Orocovis
		Orocovis 2	Orocovis	Río Orocovis
		Sana Muerto	Orocovis	Río Sana Muerto
		Negros	Corozal	Río Grande de Manatí
		Las Delicias	Ciales	Río Cialitos
50038320	Río Cibuco below Corozal	Corozal	Corozal	Río Cibuco
50039500	Río Cibuco at Vega Baja	Corozal	Corozal	Río Cibuco
		Maricao	Vega Alta	Unnamed creek
		Vega Baja	Vega Baja	Río Indio
		Almirante Sur	Vega Baja	Río Unibón
		Morovis Vieja	Morovis	Río Morovis

Table 2. Gaging stations on selected streams in Puerto Rico affected by filtration-plant withdrawals--Continued

Station number	Station name	Filtration plant name	Municipality	Supplying stream
50043000	Río de la Plata at Proyecto la Plata	Guavate	Cayey	Río Guavate
		El Cedro	Cayey	Quebrada El Cedro
		Cayey	Cayey	Río de la Plata and Quebrada Santo Domingo
		Culebras	Cayey	Río Chiquito
50043800	Río de la Plata at Comerío	Guavate	Cayey	Río Guavate
		El Cedro	Cayey	Quebrada El Cedro
		Cayey	Cayey	Río de la Plata and Quebrada Santo Domingo
		Aibonito	Aibonito	Río Usabón and Río de Aibonito
		Barranquitas	Barranquitas	Río de Barranquitas
		Comerío	Comerío	Río de la Plata
		Culebras	Cayey	Río Chiquito
50051150	Quebrada Blanca at El Jagual	Jagual	San Lorenzo	Quebrada Blanca
50051310	Río Cayaguas at Cerro Gordo	Quebrada Arenas	San Lorenzo	Quebrada Arenas
50055000	Río Grande de Loíza at Caguas	Jagual	San Lorenzo	Quebrada Blanca
		San Lorenzo	San Lorenzo	Río Cayaguas
		Quebrada Arenas	San Lorenzo	Quebrada Arenas
		San Salvador	Caguas	Quebrada Morena
		Caguas	Caguas	Río Turabo and Quebrada de las Quebradillas
		Espino 1	San Lorenzo	Río Emajagua
		Espino 2	San Lorenzo	Unnamed creek
50057000	Río Gurabo at Gurabo	Juncos 1	Las Piedras	Río Gurabo
		Juncos 2	Juncos	Río Gurabo
		Cubuy	Canóvanas	Río Cubuy
50061800	Río Canóvanas near Campo Rico	Morovis	Río Grande	Río Espíritu Santo
50063300	Río Espíritu Santo near El Verde	Morovis	Río Grande	Río Espíritu Santo
50063800	Río Espíritu Santo near Río Grande	Jiménez	Río Grande	Quebrada Grande
		El Zarzal	Río Grande	Quebrada Jiménez
50064200	Río Grande near El Verde	Guzmán Arriba	Río Grande	Río Grande

Table 2. Gaging stations on selected streams in Puerto Rico affected by filtration-plant withdrawals--Continued

Station number	Station name	Filtration plant name	Municipality	Supplying stream
50067000	Río Sabana at Sabana	Luquillo	Luquillo	Río Sabana and Río del Cristal
50071000	Río Fajardo near Fajardo	Fajardo	Fajardo	Río Fajardo
50081000	Río Humacao at Las Piedras	Humacao-Las Piedras	Humacao	Río Humacao
50106100	Río Coamo at Coamo	Coamo	Coamo	Río Coamo
50115000	Río Portugués near Ponce	Guaraguao	Ponce	Río Portugués
		Tibes	Ponce	Unnamed creek
50124200	Río Guayanilla near Guayanilla	Jagua Pasto	Guayanilla	Río Guayanilla
50136000	Río Rosario at Rosario	Maricao	Maricao	Río Maricao
50136400	Río Rosario near Hormigueros	Maricao	Maricao	Río Maricao
50138000	Río Guanajibo near Hormigueros	Maricao	Maricao	Río Maricao
		Sabana Grande	Sabana Grande	Río Guanajibo
		La Máquina	Sabana Grande	Unnamed creek
		San Germán 1	San Germán	Río Caín
		San Germán 2	San Germán	Río Hoconuco
50144000	Río Grande de Añasco near San Sebastián	Monte del Estado	Maricao	Río Lajas
		Perchas	San Sebastián	Quebrada Sumaria
		Las Mariás	Las Mariás	Río Mayaguecillo and unnamed creek
		Alto Sano	San Sebastián	Quebrada Alto Sano
		Bucarabones 1	Maricao	Quebrada Joséfa
		Bucarabones 2	Maricao	Río Guabá
		Maricao	Maricao	Río Lajas
50147800	Río Culebrinas at Highway 404 near Moca	San Sebastián 1	San Sebastián	Río Culebrinas
		San Sebastián 2	San Sebastián	Unnamed creek

Table 3. Gaging stations on selected streams in Puerto Rico affected by wastewater-treatment plant effluent

Station number	Station name	Wastewater treatment plant name	Municipality	Receiving stream
50010600	Río Guajataca above Lago Guajataca	Lares Nueva	Lares	Río Guajataca
50031200	Río Grande de Manatí near Morovis	Alturas de Orocovis	Orocovis	Río Orocovis
		Orocovis	Orocovis	Río Orocovis
50035000	Río Grande de Manatí at Ciales	Alturas de Orocovis	Orocovis	Río Orocovis
		Orocovis	Orocovis	Río Orocovis
50038100	Río Grande de Manatí at Highway 2 near Manatí	Ciales	Ciales	Río Grande de Manatí
		Alturas de Orocovis	Orocovis	Río Orocovis
		Orocovis	Orocovis	Río Orocovis
50038320	Río Cibuco below Corozal	Corozal	Corozal	Río Cibuco
50039500	Río Cibuco at Vega Baja	Morovis	Morovis	Río Indio
		Morovis Unibón	Morovis	Río Unibón
		Vega Alta	Vega Alta	Río Cibuco
		Corozal	Corozal	Río Cibuco
50043000	Río de la Plata at Proyecto La Plata	Cayey	Cidra	Río de la Plata
		El Torito	Cayey	Río de la Plata
50043800	Río de la Plata at Comerío	Aibonito	Aibonito	Río Aibonito
		Barranquitas	Barranquitas	Río Barranquitas
		Cayey	Cidra	Río de la Plata
		El Torito	Cayey	Río de la Plata
50055000	Río Grande de Loíza at Caguas	San Lorenzo	San Lorenzo	Río Grande de Loíza
50057000	Río Gurabo at Gurabo	Juncos	Juncos	Río Valenciano
50077000	Río Blanco at Río Blanco	Río Blanco Heights	Naguabo	Río Blanco
50136000	Río Rosario at Rosario	Maricao	Maricao	Río Maricao
50136400	Río Rosario near Hormigueros	Maricao	Maricao	Río Maricao
50138000	Río Guanajibo near Hormigueros	Sabana Grande	Sabana Grande	Río Guanajibo
		San Germán	San Germán	Quebrada Rodeo
		Maricao	Maricao	Río Maricao
50144000	Río Grande de Añasco near San Sebastián	Las Marías	Las Marías	Río Arenas
50147800	Río Culebrinas at Highway 404 near Moca	San Sebastián	San Sebastián	Río Culebrinas

Table 4. Flow-duration discharges for selected gaging stations in Puerto Rico

[U, unadjusted flow durations; A, adjusted flow durations. See tables 2 and 3 for reason for adjusting flows.]

Station number	Type	Discharge equaled or exceeded for the indicated percentage of time (cubic feet per second)														
		99	98	95	90	80	70	50	30	20	10	5	2	1		
50010600	U	3.0	3.3	4.0	4.9	6.6	8.8	16	31	48	81	129	223	274		
	A	5.5	5.7	6.4	7.2	8.8	11	18	32	48	81	129	221	259		
50011200	U	0.8	0.8	0.9	1.1	1.3	1.6	2.4	4.4	21	147	295	468	514		
50011400	U	6.2	6.9	7.8	9.0	12	14	18	25	68	194	489	1,110	1,240		
	A	9.8	10	12	13	15	17	21	26	40	179	604	1,080	1,220		
50014800	U	26	27	30	34	40	48	67	94	127	200	301	458	619		
	A	27	29	33	36	39	50	70	97	128	200	302	460	613		
50015700	U	29	31	35	40	49	57	79	119	169	309	548	928	1,410		
	A	32	34	38	43	51	60	82	122	170	303	545	920	1,420		
50021500	U	0.0	0.1	0.2	0.5	0.9	1.4	2.9	6.6	14	45	105	205	271		
	A	1.5	1.6	1.7	1.9	2.3	2.6	4.0	7.0	11	29	80	165	224		
50023000 ¹	U	1.9	2.0	2.4	3.2	4.7	6.1	8.9	14	19	30	43	74	103		
50025155	U	2.7	3.0	3.6	4.4	6.2	7.9	12	19	25	39	63	105	143		
	A	2.9	3.2	3.8	4.5	6.3	8.2	12	19	25	39	63	406	144		
50027750	U	29	35	45	57	82	121	258	464	588	804	1,110	1,690	2,060		
50028000	U	9.8	11	14	17	20	24	33	47	59	84	119	192	271		
50028400	U	11	13	20	27	38	46	64	92	121	177	250	376	488		
	A	14	16	22	29	39	47	63	89	116	172	245	367	468		
50029000	U	88	99	116	141	188	238	362	549	700	989	1,370	1,990	2,510		
	A	91	102	120	143	190	237	358	549	702	994	1,380	1,990	2,540		
50030460	U	0.6	0.7	0.8	1.0	1.1	1.3	2.0	3.8	6.2	12	27	62	115		
	A	3.5	3.5	3.6	3.8	4.1	4.3	4.8	6.3	8.5	14	28	60	106		
50031200	U	7.8	11	18	23	30	36	50	79	108	178	298	524	780		
	A	13	15	20	25	32	38	52	80	111	180	295	511	787		
50031500 ¹	U	1.9	2.1	2.5	2.9	3.4	3.9	4.9	7.0	9.0	16	31	70	117		

Table 4. Flow-duration discharges for selected gaging stations in Puerto Rico--Continued

Station number	Type	Discharge equaled or exceeded for the indicated percentage of time (cubic feet per second)												
		99	98	95	90	80	70	50	30	20	10	5	2	1
50033500	U	2.7	3.0	3.5	4.2	5.2	6.2	8.8	15	24	44	83	209	404
50034000	U	3.4	3.7	4.4	5.5	7.6	9.1	14	21	31	64	129	263	394
50035000	U	25	32	43	53	68	81	117	182	253	455	811	1,470	2,280
	A	29	35	44	55	70	83	119	184	255	452	813	1,480	2,270
50038100	U	52	58	73	87	106	124	172	262	365	665	1,130	2,150	3,310
	A	59	65	78	94	111	130	174	266	372	661	1,140	2,150	3,400
50038320	U	1.9	2.7	3.8	5.5	7.7	9.3	14	21	28	50	90	184	288
	A	3.2	3.8	5.0	6.7	8.8	10	15	22	30	51	90	185	294
50039500	U	12	14	18	24	33	41	60	95	132	231	376	697	1,100
	A	16	18	22	28	37	44	64	100	140	238	385	685	1,070
50040000	U	0.5	1.4	3.2	5.3	8.7	12	18	27	36	57	102	196	315
50043000	U	4.1	4.9	6.6	8.8	13	17	29	52	80	160	318	830	1,480
	A	9.3	10	12	14	18	22	34	57	84	158	322	821	1,470
50043800	U	7.8	8.9	13	16	20	23	34	54	74	130	288	685	1,370
	A	16	18	20	24	28	32	42	62	80	137	270	648	1,160
50045010	U	0.0	0.0	0.0	0.0	0.0	0.1	1.8	33	86	201	432	955	1,760
50046000	U	7.7	10	14	19	28	42	91	175	259	500	896	1,790	2,850
50047850	U	3.0	3.2	3.8	4.8	7.0	8.9	13	20	27	59	108	238	416
50048770	U	2.1	2.4	3.1	3.9	5.0	6.0	7.9	13	19	39	69	122	165
50049000	U	1.2	1.7	2.4	3.5	5.5	7.7	12	20	28	53	109	227	341
50049100	U	1.5	2.5	7.1	9.5	13	16	22	36	61	119	206	319	415
50050900	U	4.6	5.0	5.8	6.9	8.7	11	15	22	29	49	87	196	297
50051150	U	0.5	0.5	0.7	1.0	1.5	1.8	2.6	4.1	6.0	12	23	50	98
	A	0.7	0.8	1.0	1.3	1.7	2.0	2.8	4.3	6.0	12	22	49	90
50051180	U	0.5	0.6	0.7	0.9	1.2	1.4	2.0	3.3	4.8	10	22	55	97

Table 4. Flow-duration discharges for selected gaging stations in Puerto Rico--Continued

Station number	Type	Discharge equaled or exceeded for the indicated percentage of time (cubic feet per second)												
		99	98	95	90	80	70	50	30	20	10	5	2	1
50051310	U	8.8	9.3	11	13	16	18	24	34	43	68	109	246	437
50053050 ¹	A	13	13	14	16	18	21	28	37	46	71	110	247	434
	U	3.8	4.8	6.1	7.2	8.7	10	14	20	26	43	69	148	277
50055000	U	22	24	31	40	57	73	109	167	220	358	624	1,300	2,250
50056400	A	35	39	46	54	72	87	121	179	236	379	632	1,300	2,250
	U	2.9	3.7	5.3	7.0	10	13	19	30	41	72	143	335	583
50057000	U	8.4	10	14	18	26	32	50	83	118	209	381	810	1,470
50059050	A	7.4	9.1	13	18	25	32	49	82	118	210	380	807	1,460
	U	1.1	1.7	2.7	4.2	5.7	6.8	10	62	156	407	726	1,620	3,290
50061300	U	1.2	1.4	1.6	2.0	2.9	3.8	6.5	12	16	29	61	221	396
50061800	U	2.7	3.1	4.0	5.1	6.7	8.3	13	20	27	44	74	157	298
50062500	A	5.6	8.8	12	13	15	17	21	28	35	53	85	168	302
	U	1.6	1.7	1.9	2.2	2.5	3.0	4.4	6.4	8.2	14	26	70	139
50063250	U	3.9	4.1	4.6	5.5	6.2	7.4	12	20	30	50	78	134	192
50063300	U	3.1	3.3	3.8	4.6	6.1	7.5	11	19	29	58	109	225	348
50063440	A	3.1	3.4	4.0	4.9	6.4	7.9	12	20	30	58	117	249	376
	U	0.0	0.0	0.2	0.4	0.9	1.5	2.8	5.5	8.8	17	29	48	61
50063500	U	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.4	0.7	1.2	2.4	3.6
50063800	U	5.9	6.6	8.2	11	14	17	26	45	68	125	208	375	534
50064200	A	6.2	6.9	8.5	11	14	17	26	45	68	125	205	368	531
	U	3.4	4.3	5.5	6.8	9.1	12	18	29	44	83	146	277	477
50065500	A	3.8	4.5	5.6	7.0	9.3	12	18	29	43	81	145	269	462
	U	11	12	14	16	21	24	34	50	66	104	158	287	444
50065700	U	8.8	11	14	18	24	29	41	65	90	148	230	414	594
50067000	U	1.4	1.6	2.0	2.7	4.0	5.3	8.4	14	19	36	72	144	214
50067000	A	4.3	4.6	5.0	5.7	7.0	8.3	11	17	22	38	74	150	211

Table 4. Flow-duration discharges for selected gaging stations in Puerto Rico--Continued

Station number	Type	Discharge equaled or exceeded for the indicated percentage of time (cubic feet per second)											
		99	98	95	90	80	70	50	30	20	10	5	1
50071000	U	3.9	5.2	7.7	11	16	21	33	53	73	127	219	431
	A	14	15	18	21	26	30	42	62	82	137	233	440
50072000 ¹	U	9.3	11	16	20	26	31	44	66	84	133	200	332
50073400	U	0.3	0.3	0.5	0.7	1.0	1.4	2.5	4.4	6.5	13	24	68
50075000	U	2.7	3.3	3.9	4.6	5.5	6.3	8.3	12	17	29	46	77
50077000	U	0.5	0.9	1.5	2.3	6.5	13	32	59	85	154	282	551
	A	0.5	0.9	1.5	2.2	6.3	12	30	58	84	152	281	564
50081000	U	3.9	4.7	5.8	6.9	8.4	10	14	18	22	32	47	93
	A	9.0	9.6	11	12	13	15	18	22	26	36	51	93
50082800	U	3.5	4.2	5.2	5.9	7.7	9.6	14	20	27	49	95	212
50090500	U	3.1	3.5	4.3	5.2	6.4	7.6	11	16	21	33	48	84
50092000	U	6.8	8.0	10	12	16	20	28	43	59	99	178	365
50093050	U	1.8	5.5	10	16	24	32	47	70	91	153	242	415
50100200	U	0.0	0.0	0.0	0.1	0.3	0.5	1.1	2.1	3.0	6.4	23	116
50100450	U	0.0	0.0	0.1	0.3	0.6	0.9	2.0	3.4	4.8	8.9	17	36
50106100	U	0.9	1.1	1.5	2.0	3.0	4.3	7.1	12	19	40	75	149
	A	3.5	3.7	4.1	4.6	5.6	6.8	9.8	14	21	39	75	145
50108000	U	0.0	0.0	0.0	0.0	0.2	0.5	1.4	3.5	5.9	14	31	76
50110900	U	0.7	0.8	1.0	1.2	1.9	2.6	3.9	7.9	15	30	54	97
50111500	U	0.8	1.1	1.6	2.5	4.2	5.4	8.3	24	48	103	175	336
50112500	U	1.7	2.0	2.4	3.1	4.3	5.5	9.1	17	25	41	62	102
50113800	U	3.3	3.5	4.1	4.7	6.2	8.4	14	22	32	59	98	157
50114000	U	3.4	3.8	4.6	5.6	7.3	9.4	16	31	46	78	117	184
50114390	U	3.4	3.8	4.1	4.5	5.7	7.5	13	23	39	90	210	443
50115000	U	1.7	1.9	2.4	3.0	4.0	5.1	8.2	15	22	41	65	111
	A	2.0	2.2	2.8	3.8	5.5	7.5	11	17	24	42	67	112

Table 4. Flow-duration discharges for selected gaging stations in Puerto Rico--Continued

Station number	Type	Discharge equaled or exceeded for the indicated percentage of time (cubic feet per second)												
		99	98	95	90	80	70	50	30	20	10	5	2	1
50121000 ²	U	0.2	0.8	1.6	3.1	6.7	11	19	37	57	108	177	295	427
50124000 ¹	U	1.5	1.8	2.5	3.3	4.7	5.8	10	19	29	50	77	112	153
50124200	U	1.6	2.0	2.7	3.5	4.7	6.1	10	19	28	52	89	149	216
	A	1.9	2.3	3.1	3.9	5.1	6.4	10	18	28	51	87	149	216
50125790	U	2.7	3.0	3.5	4.1	5.9	7.3	12	24	34	56	81	128	166
50129500	U	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14	64	150	222	370	527
50136000	U	5.4	6.7	8.9	11	15	20	32	51	70	113	167	252	346
	A	6.3	7.6	9.6	11	15	19	30	49	67	108	160	242	342
50136400	U	6.7	7.5	9.5	11	14	17	27	47	70	117	163	225	306
	A	7.5	8.4	9.9	11	14	17	27	47	70	117	163	226	316
50138000	U	9.9	12	16	21	30	40	76	147	230	444	715	1,160	1,670
	A	12	14	19	24	33	43	79	152	235	448	724	1,180	1,690
50141000	U	6.9	7.4	8.7	10	13	15	22	35	46	68	108	189	301
50142700	U	1.2	1.4	2.5	5.0	9.6	13	21	32	42	70	109	178	257
50144000	U	48	52	62	74	95	119	187	312	420	660	943	1,420	1,850
	A	50	55	65	76	97	121	187	312	415	659	940	1,430	1,850
50147800	U	25	28	34	42	58	76	136	239	345	600	1,000	1,890	2,860
	A	28	31	37	45	61	79	139	242	346	612	999	1,890	2,860

¹ Flow-duration discharges were not adjusted for withdrawals because the filtration plant upstream from the gaging station was not in operation during the gaging station recording period.

² Flow-duration discharges were not adjusted for withdrawals because the Peñuelas filtration plant upstream from the gaging station withdraws water from the Lago Garzas and not from the Río Talaboa.

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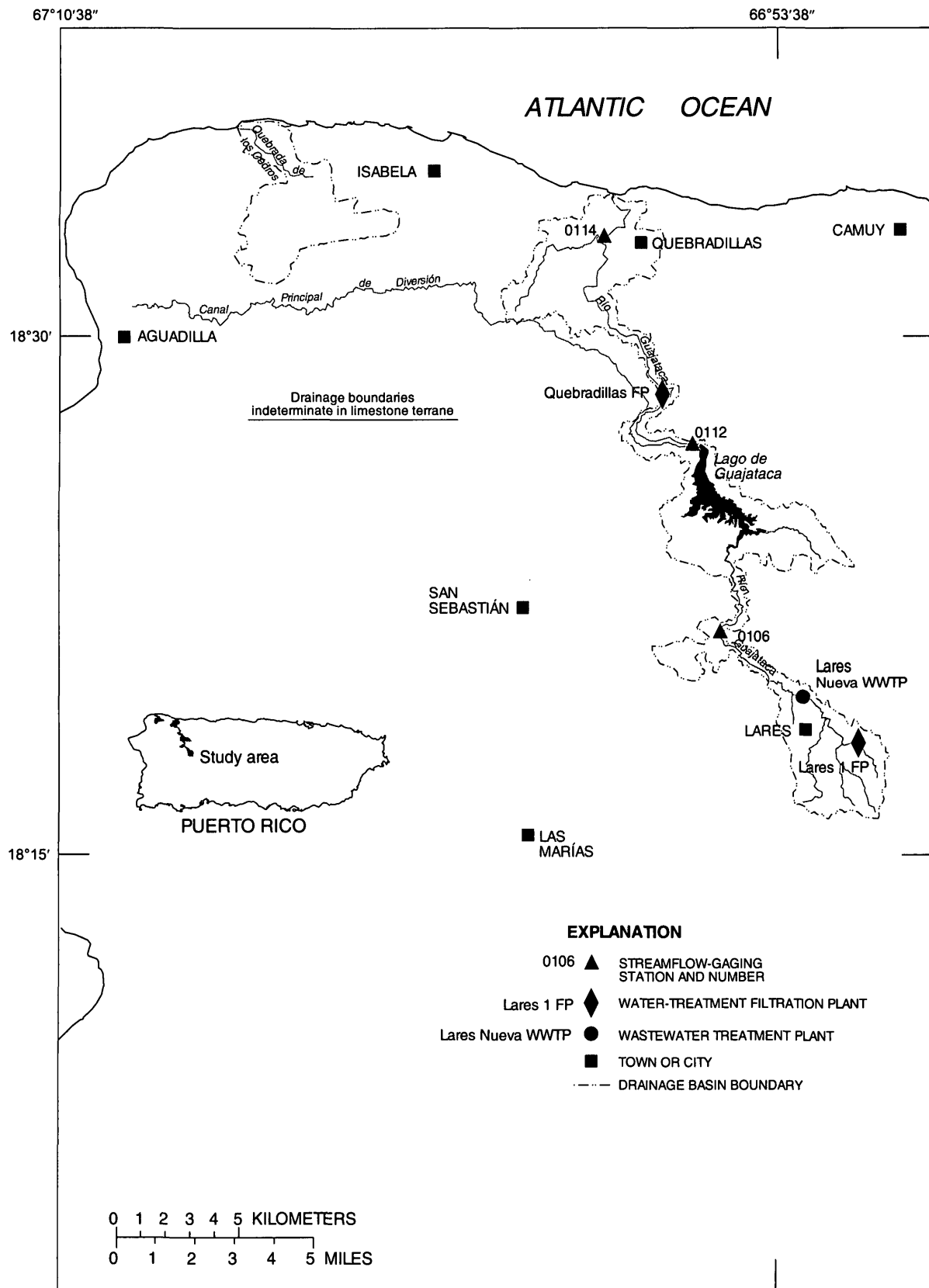


Figure 2. Location of gaging stations and water-treatment plants in the Río Guajataca basin, Puerto Rico.

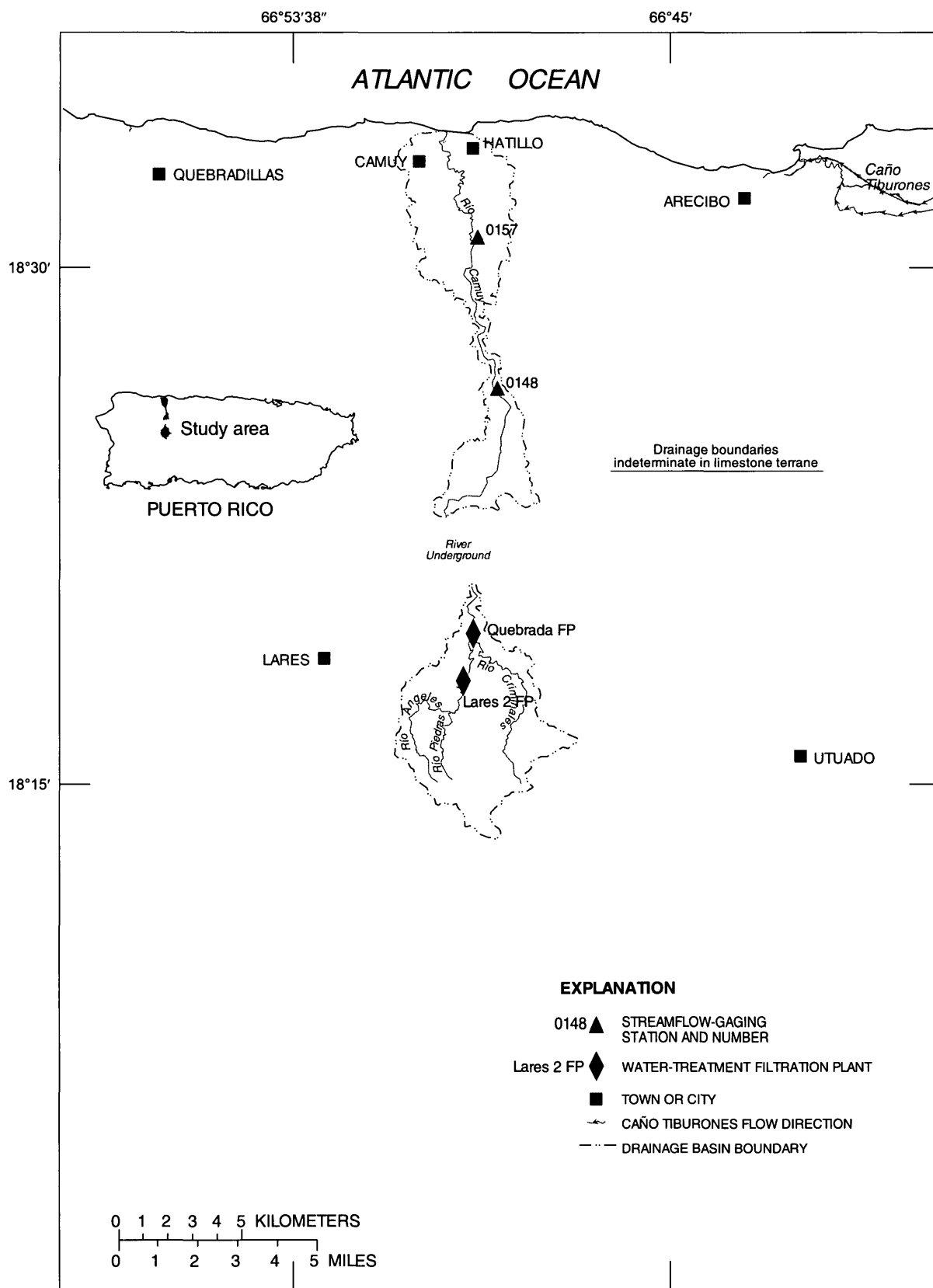


Figure 3. Location of gaging stations and water-treatment plants in the Río Camuy basin, Puerto Rico.

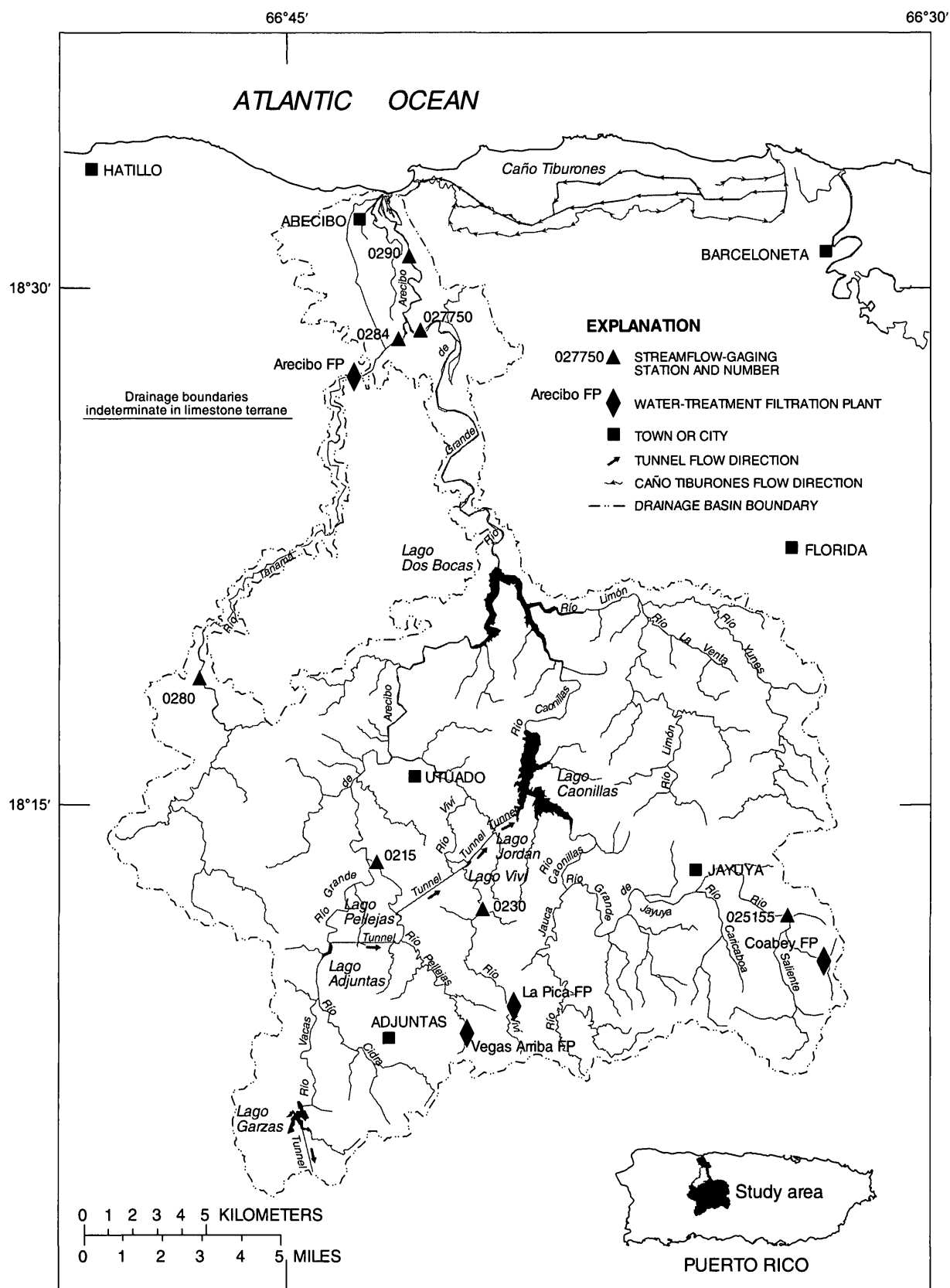


Figure 4. Location of gaging stations and water-treatment plants in the Río Grande de Arecibo basin, Puerto Rico.

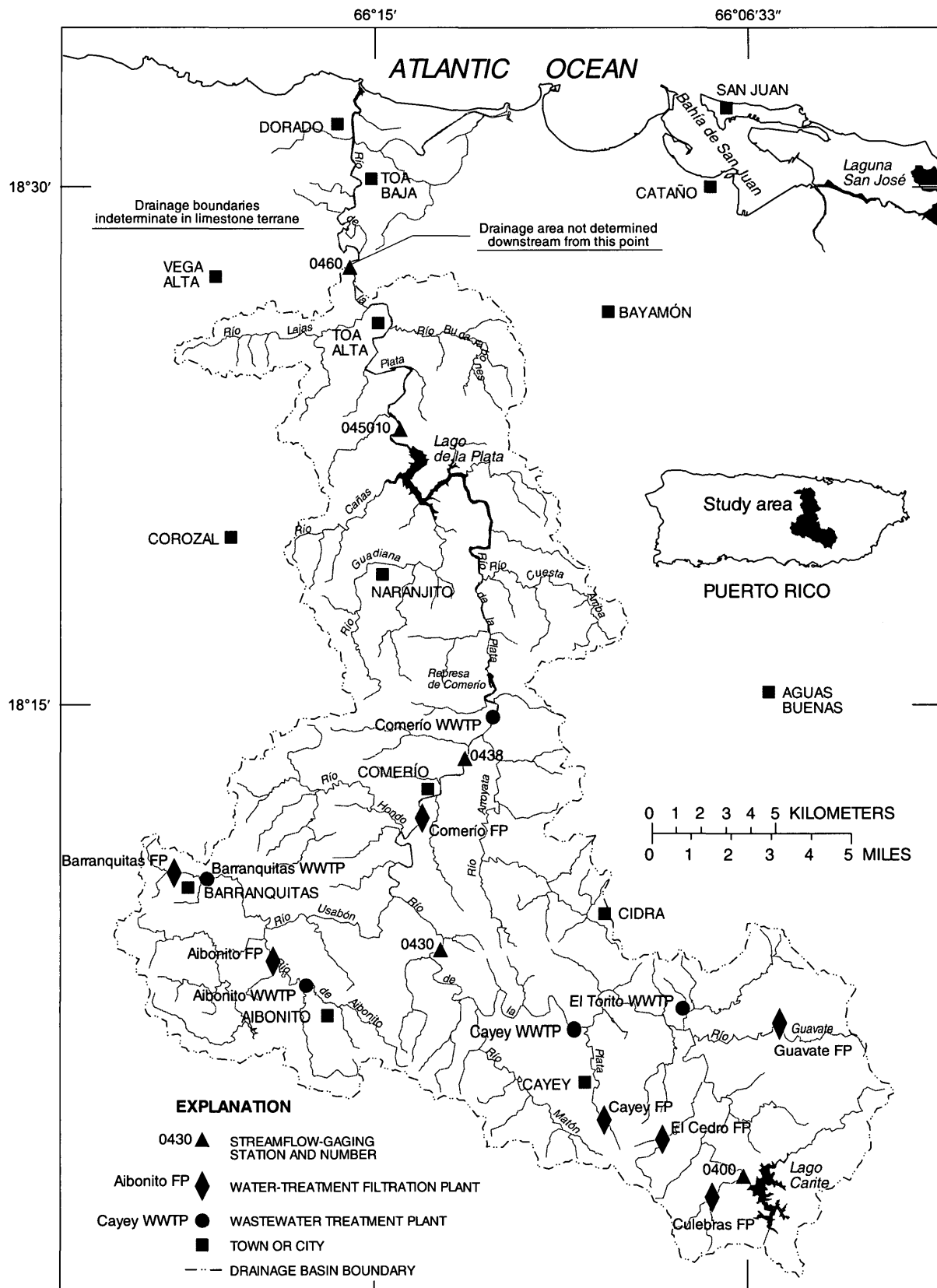


Figure 7. Location of gaging stations and water-treatment plants in the Río de la Plata basin, Puerto Rico.

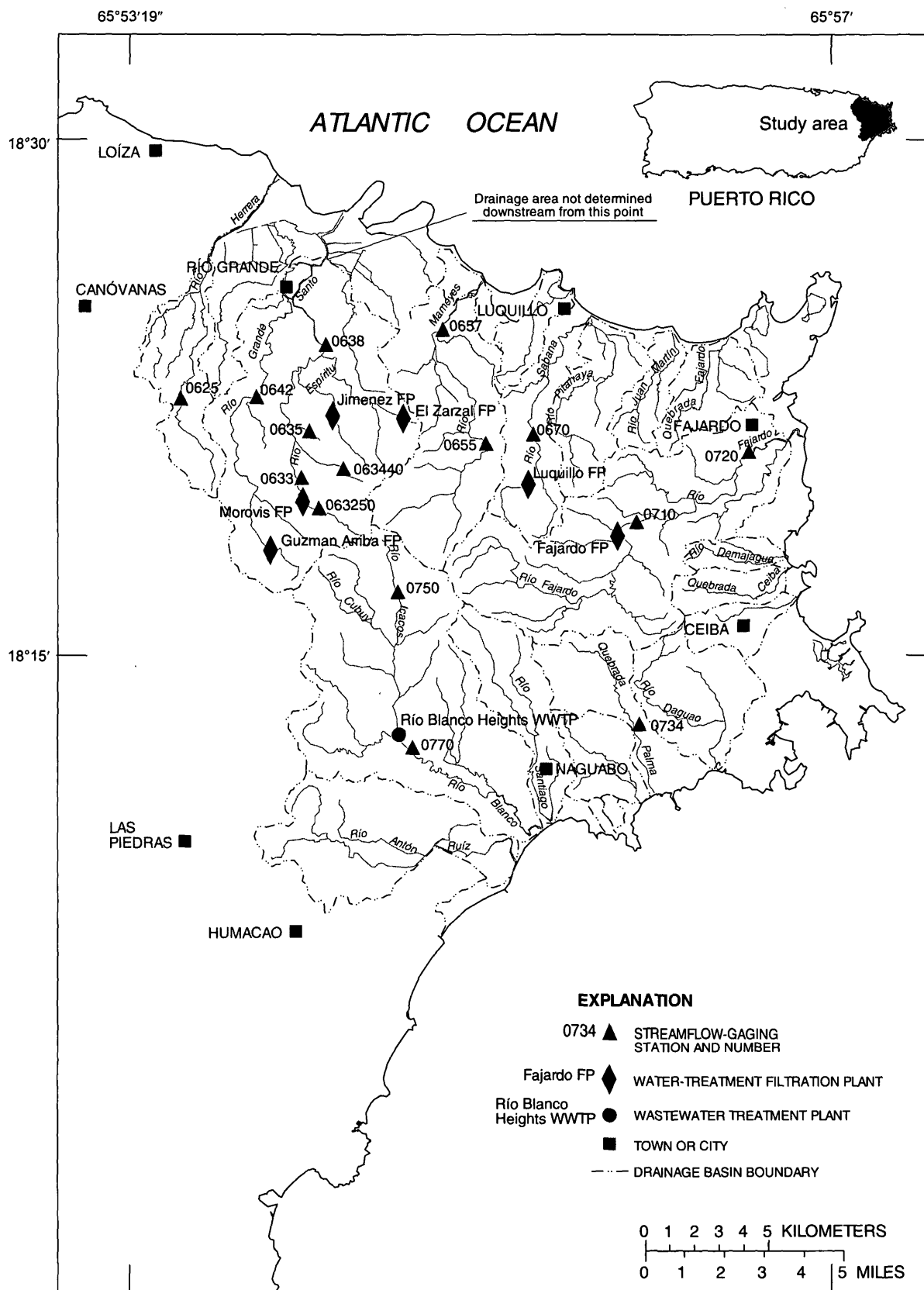


Figure 9. Location of gaging stations and water-treatment plants in the Río Herrera to Río Antón Ruíz basins, Puerto Rico.

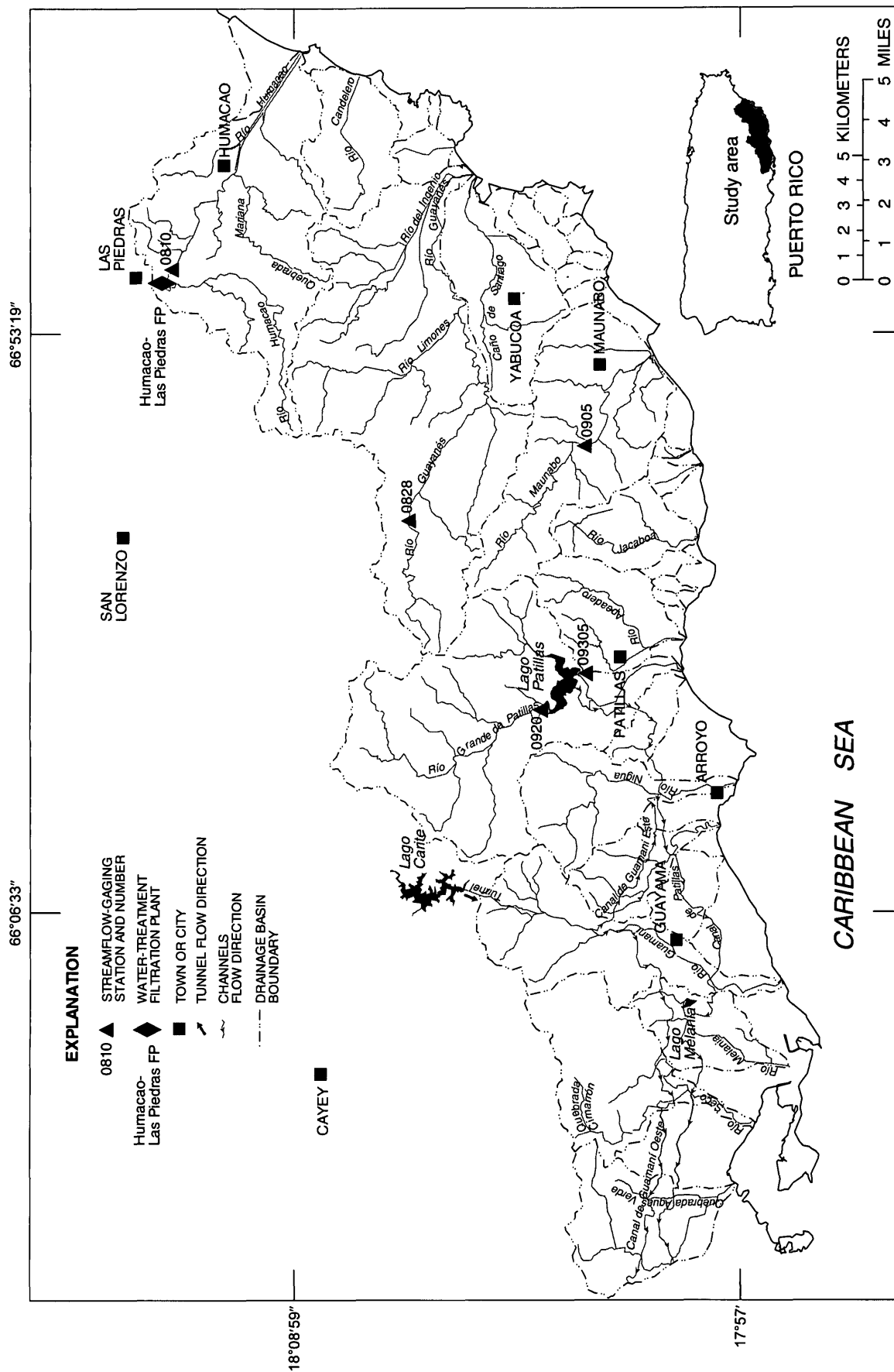
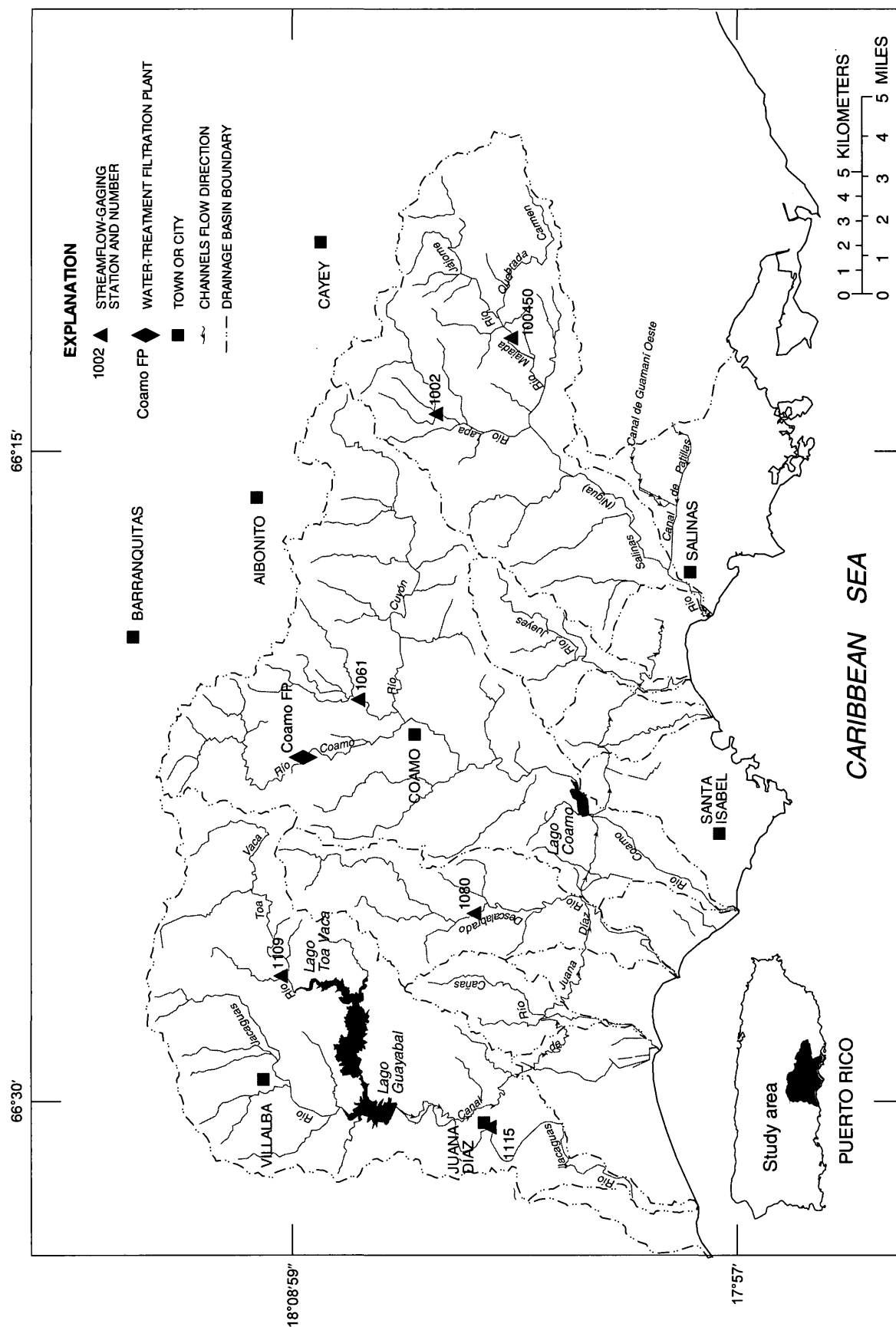


Figure 10. Location of gaging stations and water-treatment plants in the Río Humacao to Quebrada 'Aguas Verde basins, Puerto Rico.



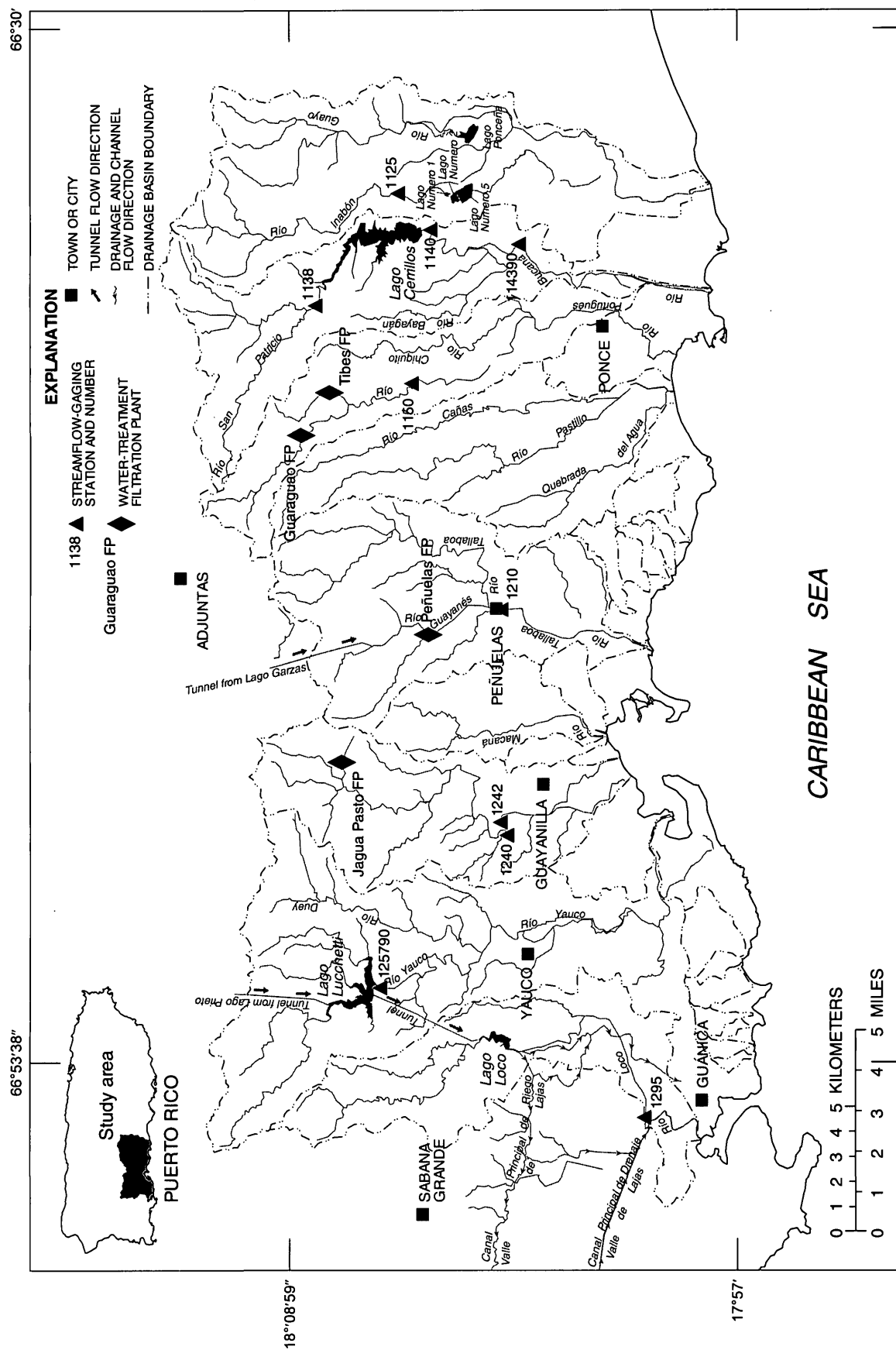


Figure 12. Location of gaging stations and water-treatment plants in the Río Inabón to Río Loco basins, Puerto Rico.

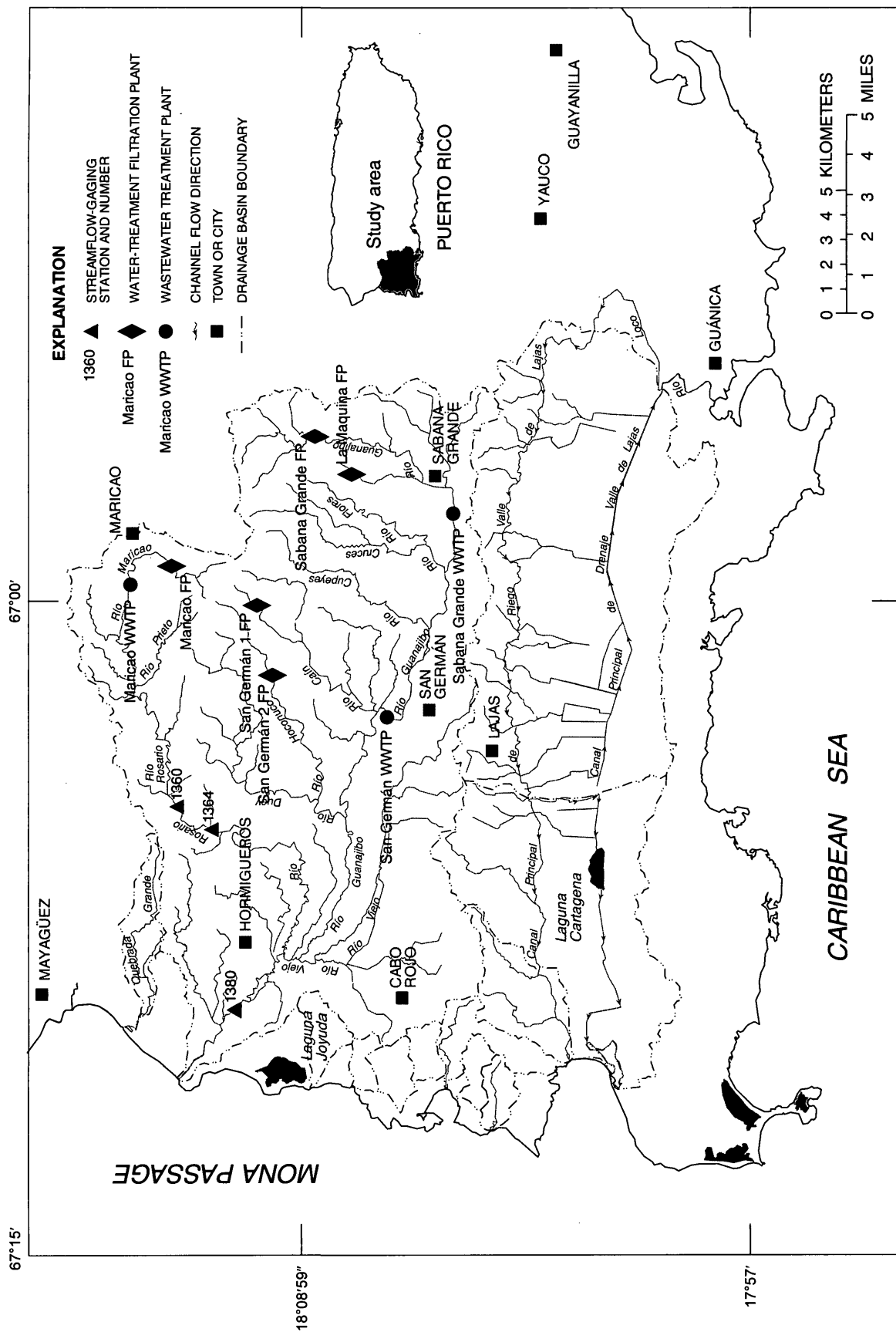


Figure 13. Location of gaging stations and water-treatment plants in the Río Guanajibo basin, Puerto Rico.

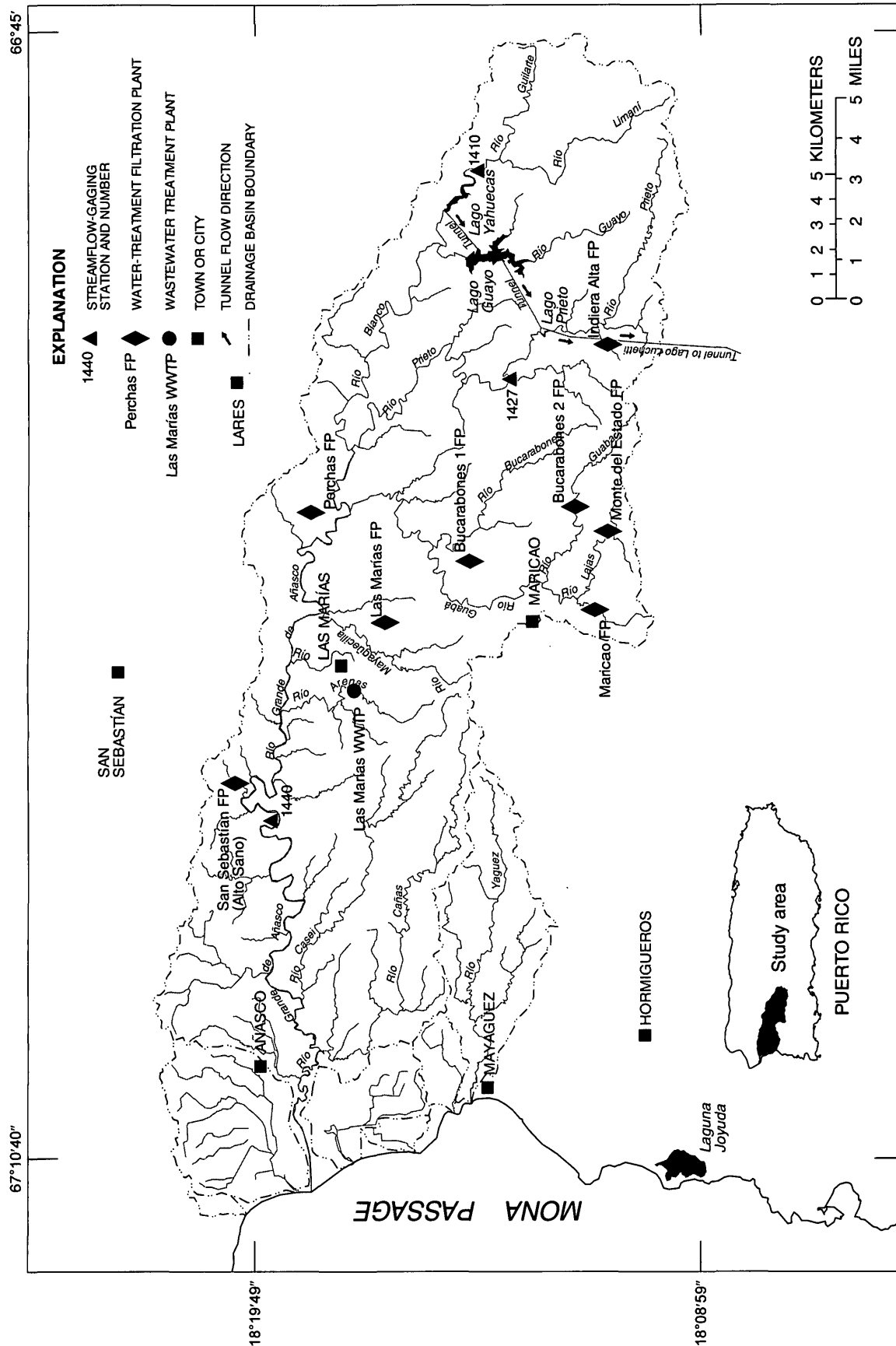


Figure 14. Location of gaging stations and water-treatment plants in the Río Yagüez to Río Grande de Añasco basins, Puerto Rico.

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